Overview of the CERES Edition 4 Multilayer Cloud Properties

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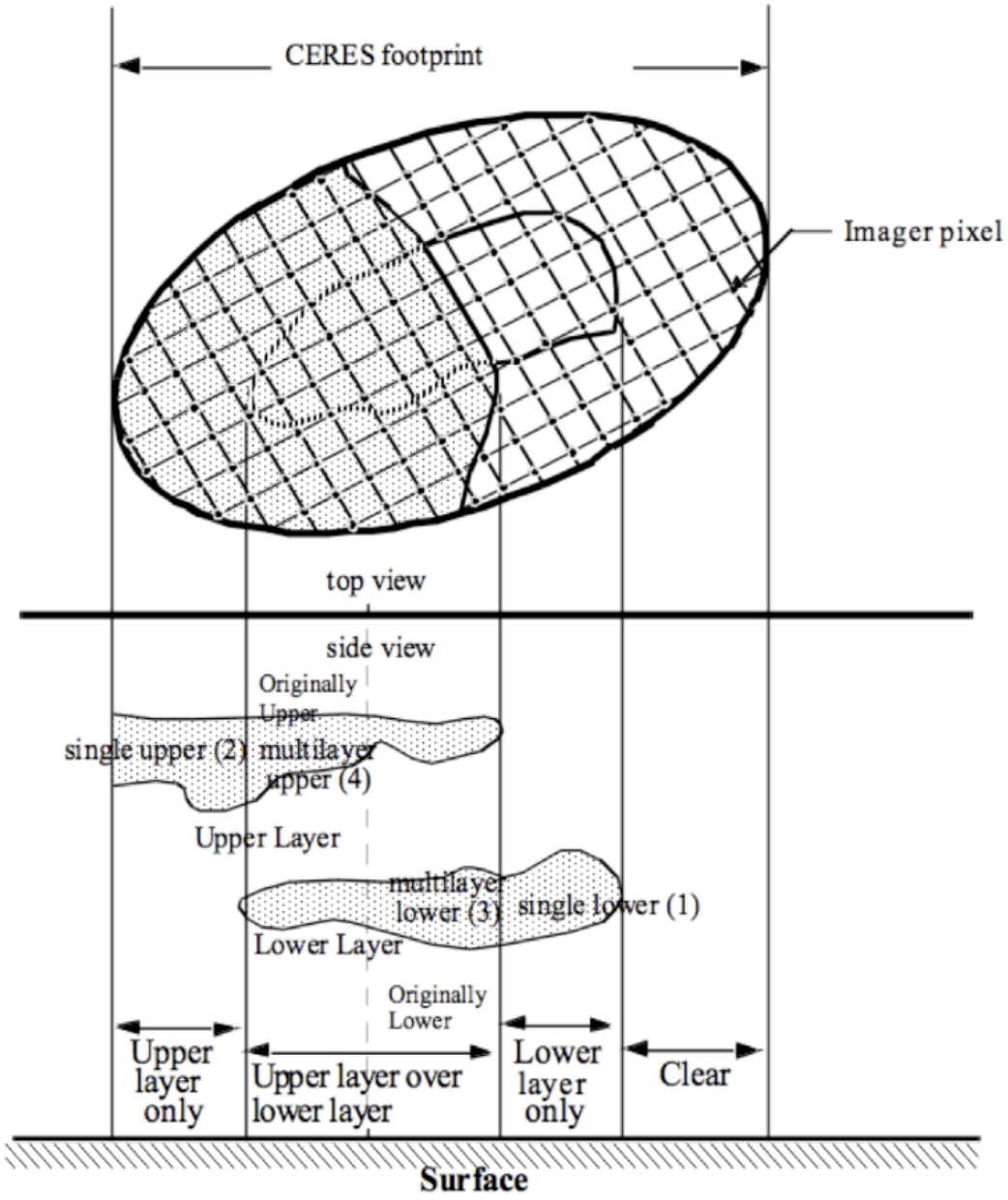
Outline

- Methodology -
  Development of the new CERES Edition 4 multilayer cloud properties.
  Constraint by the infrared and visible measurements.
  Relationship to the CERES single-layered optical and microphysical properties.

- Results –
  What to expect in the CERES Ed4 multilayer cloud properties?
  What to expect in their retrieval limitations?

- Aspects of the passive and active satellite remote sensing –
  Inferences from the merged C3M (CALIPSO/CloudSat/CERES MODIS) data.

CERES Edition 4 Multilayer Cloud Parameters



Percent coverage and layer mean cloud properties:

i. Coverage of single-layer upper clouds with Pc < 500mb

ii. Coverage of single-layer lower clouds with Pc > 500mb

iii. Coverage of multilayer clouds with upper-layer Pc < 500mb and lower-layer Pc > 500mb

CERES Two-Layered Cloud Retrieval Systems

- Constraints and relationships:
- Upper-layer and lower-layer B(T_c) and ε_c constrained by the infrared radiance measurement.
- Upper-layer and lower-layer τ_c constrained by both the visible reflectance measurement and CERES single-layered optical depth.
- Upper-layer ice $R_{e3.7}/R_{e2.1}$ and lower-layer water $r_{e3.7}/r_{e2.1}$ employed initial guesses from good CERES single-layered retrievals within the processing domain.

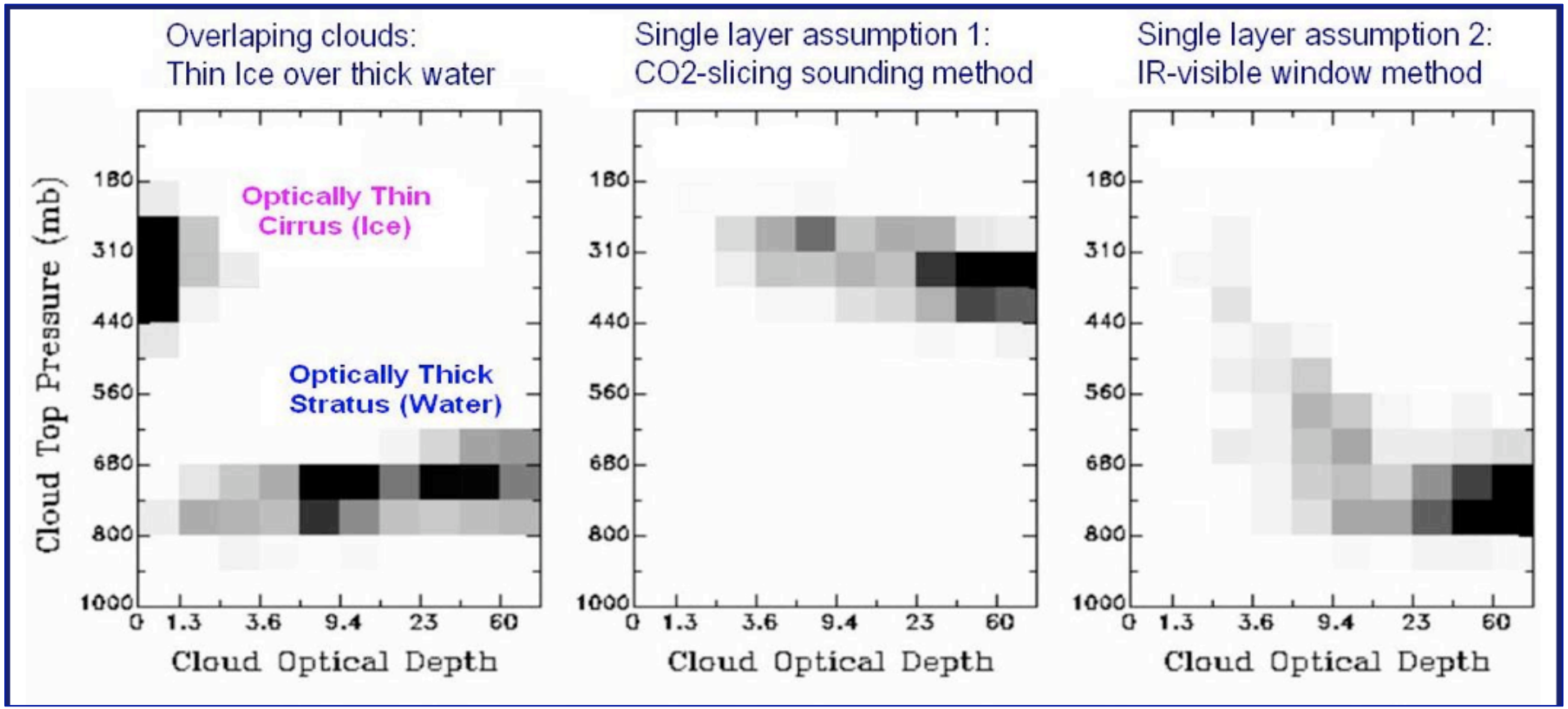
Upper layer cloud: P_c , T_c , z_c , ε_c, τ_c , $R_{e\text{-}3.7}$, $R_{e\text{-}2.1}$ (ice phase)

Lower layer cloud: P_c , T_c , z_c , ε_c, τ_c , $r_{e\text{-}3.7}$, $r_{e\text{-}2.1}$ (water phase)

Surface property data

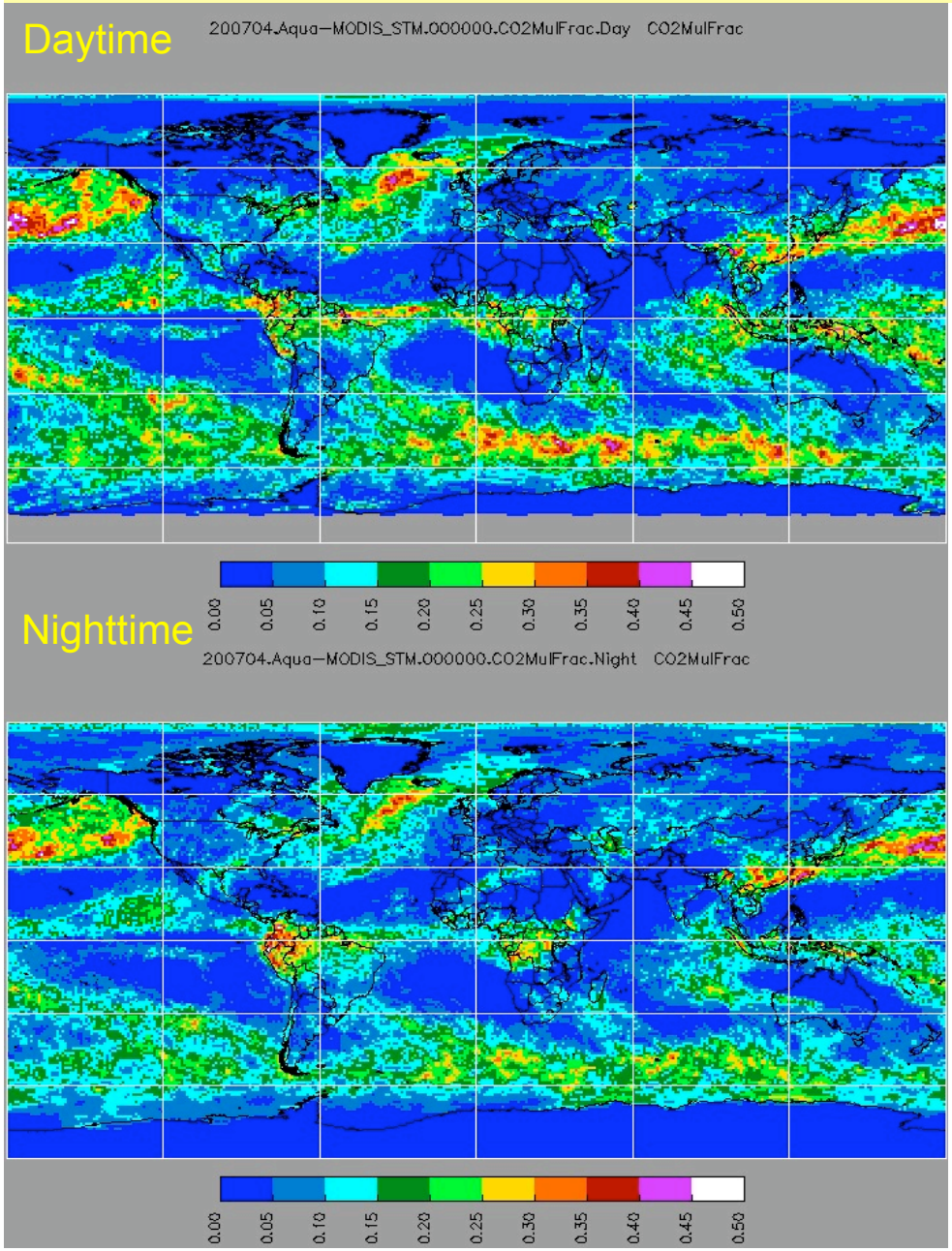
Why Retrieving Two-Layered Clouds?

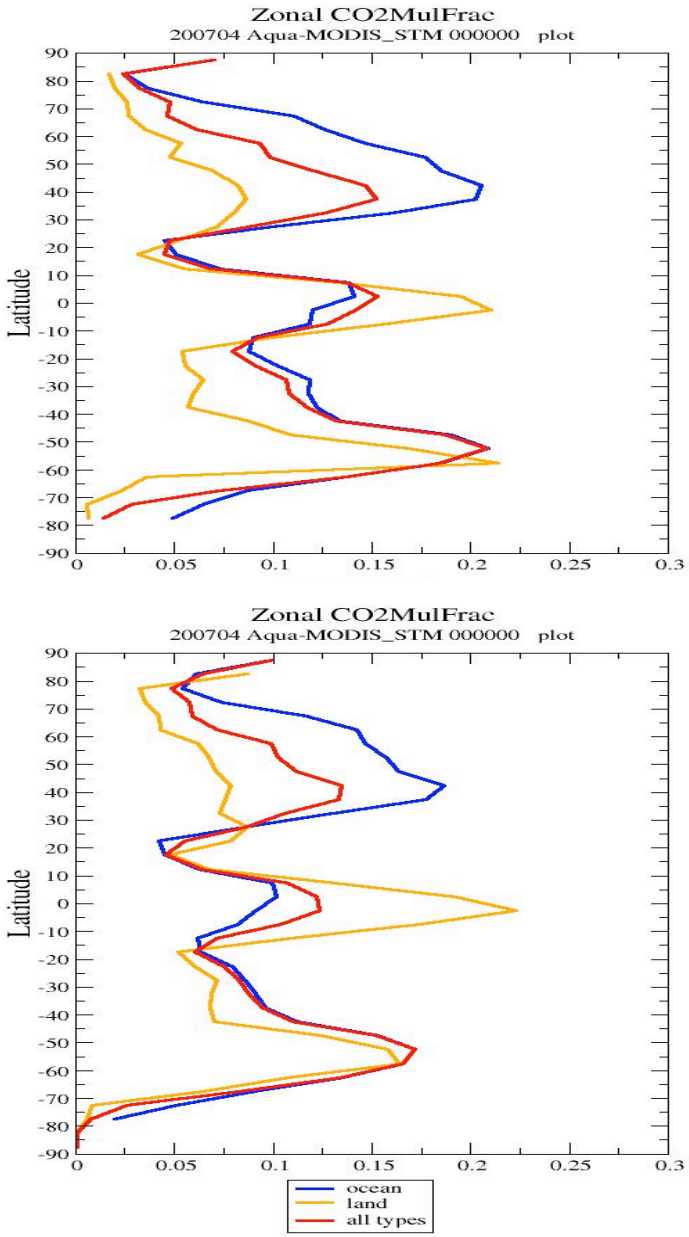
- Improvement in satellite retrieved upper cloud top altitude is not sufficient.
- Need to account for overlapped lower layer cloud.



CERES Ed4 Multilayer Cloud Fractions

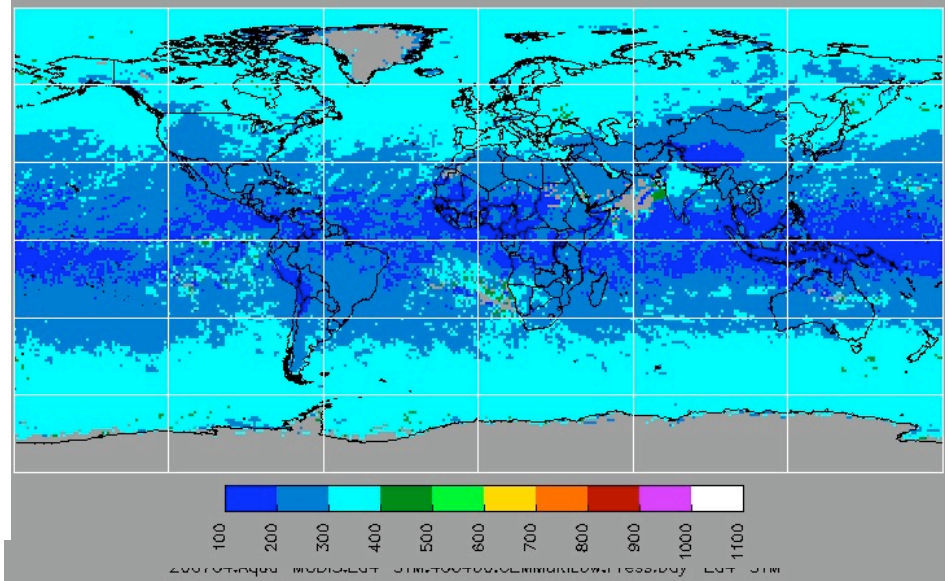
Daytime



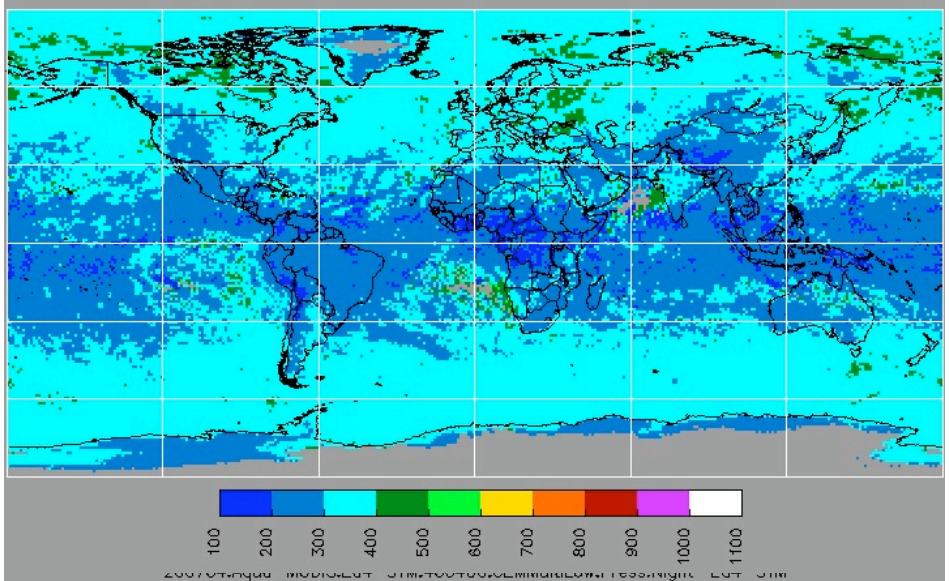


CERES Ed4 Upper & Lower-Layer Cloud Top Pressures

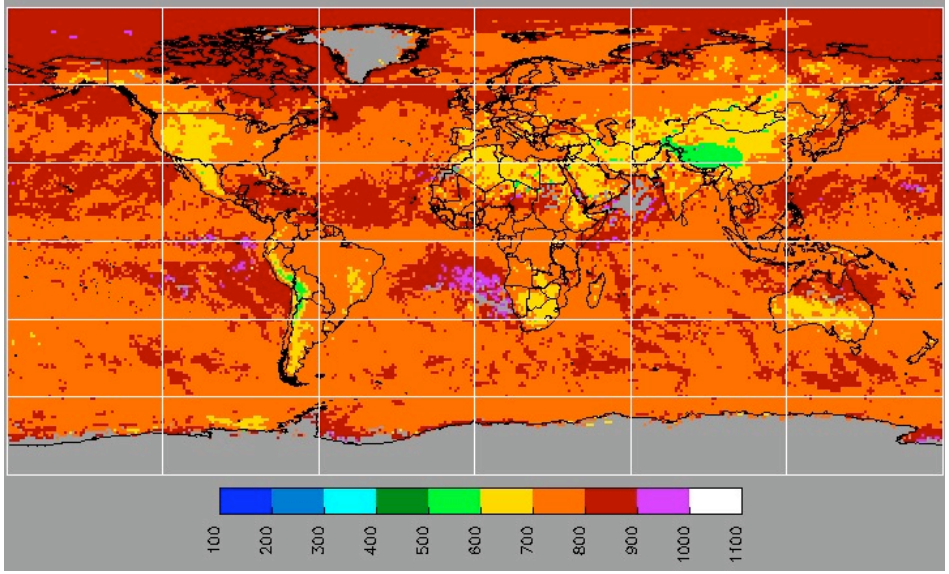
Daytime Upper



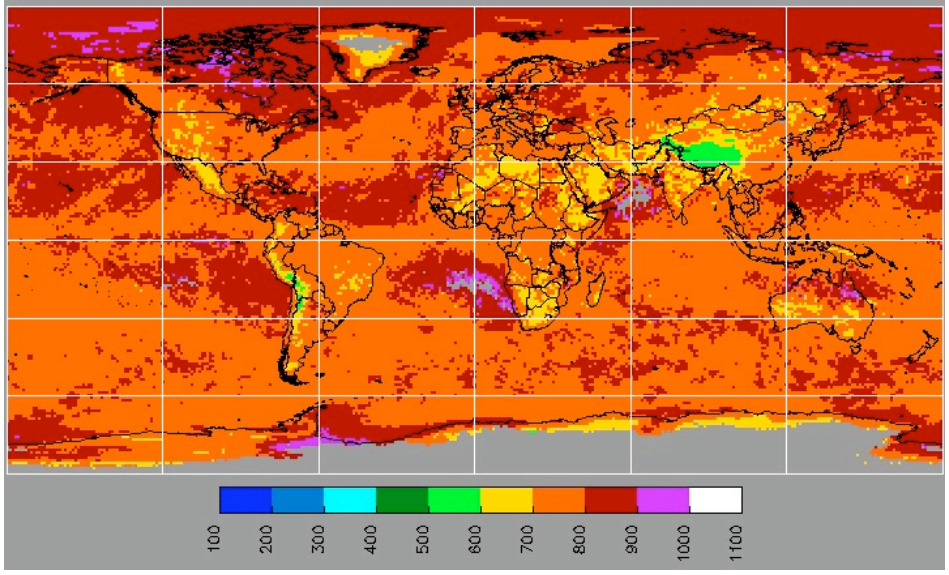
Nighttime Upper



Daytime Lower

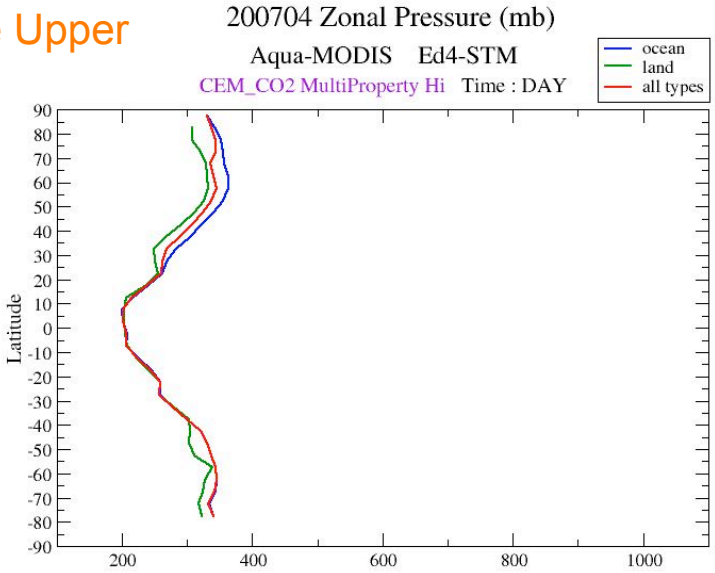


Nighttime Lower

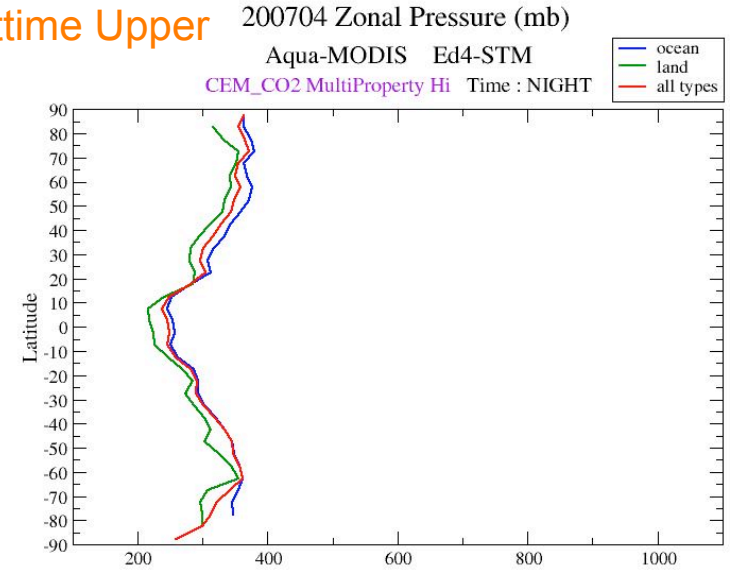


CERES Ed4 Upper & Lower-Layer Cloud Top Pressures

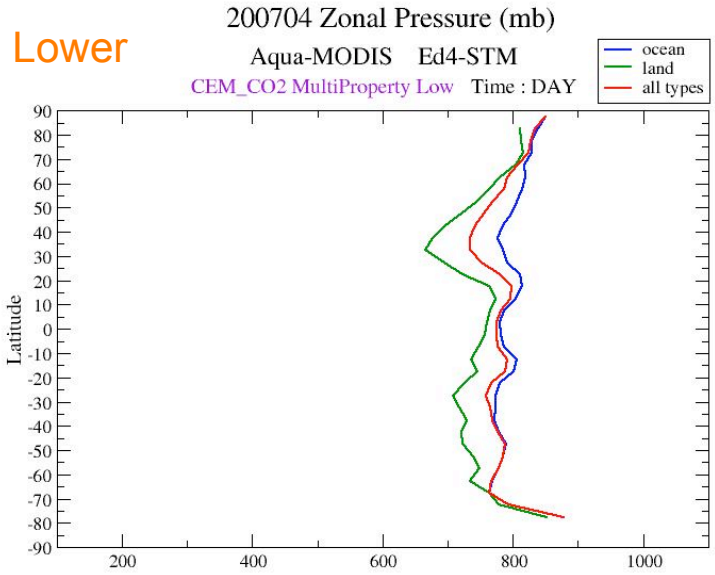
Daytime Upper



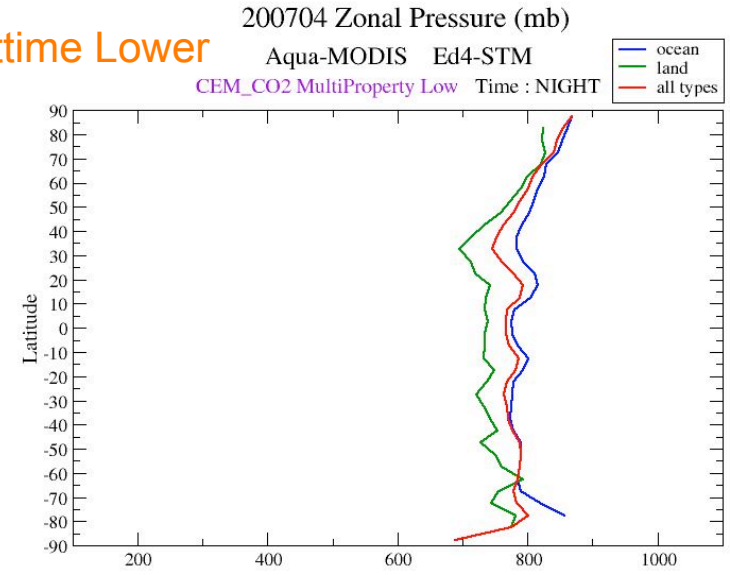
Nighttime Upper



Daytime Lower

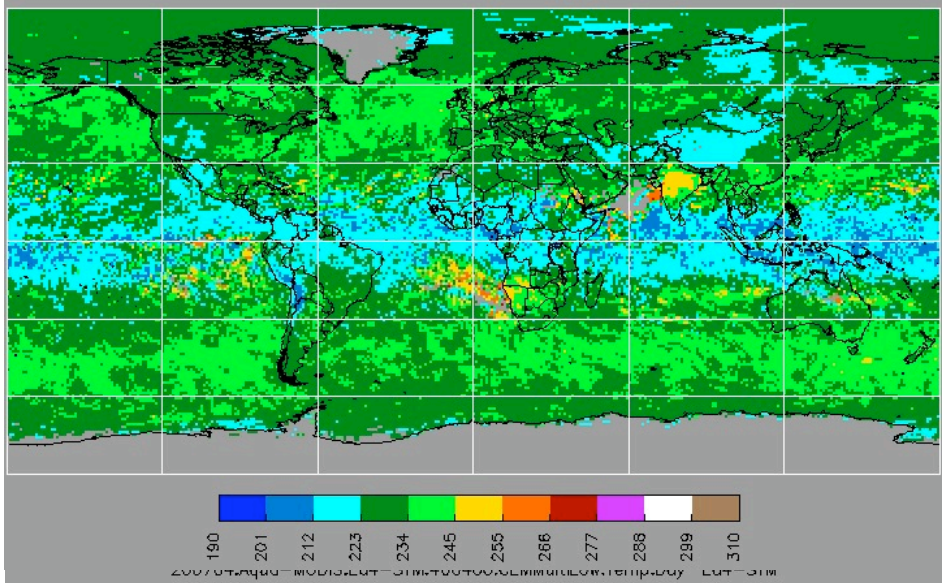


Nighttime Lower

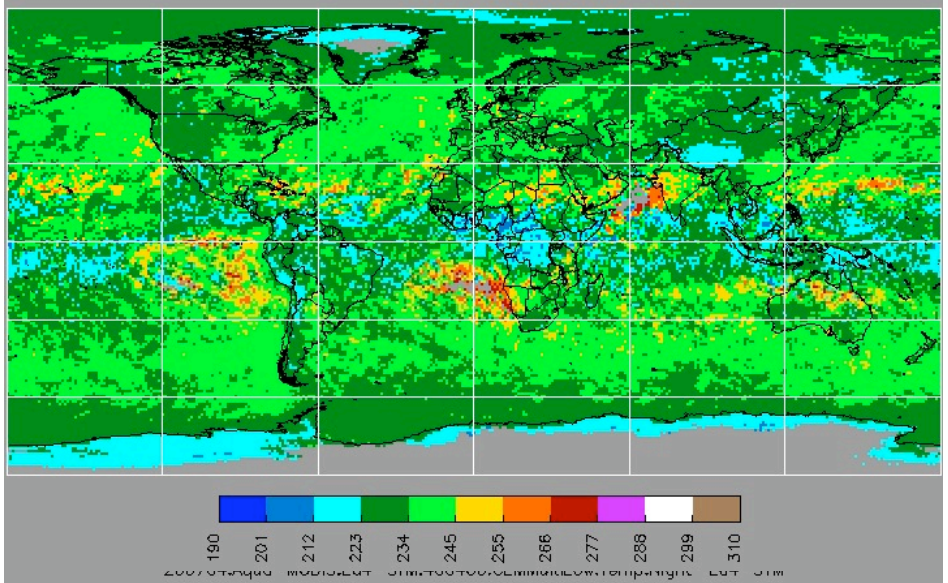


CERES Ed4 Upper & Lower-Layer Cloud Top Temperatures

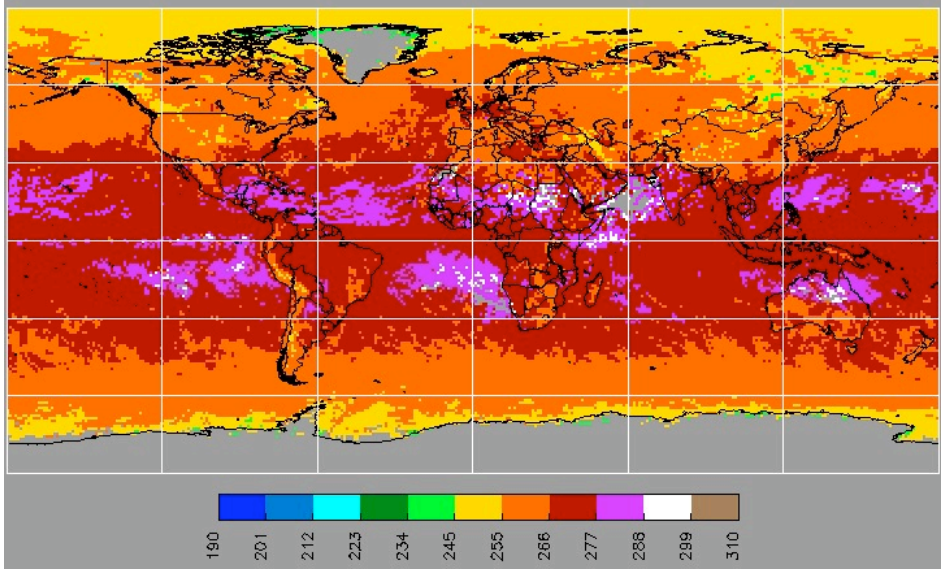
Daytime Upper



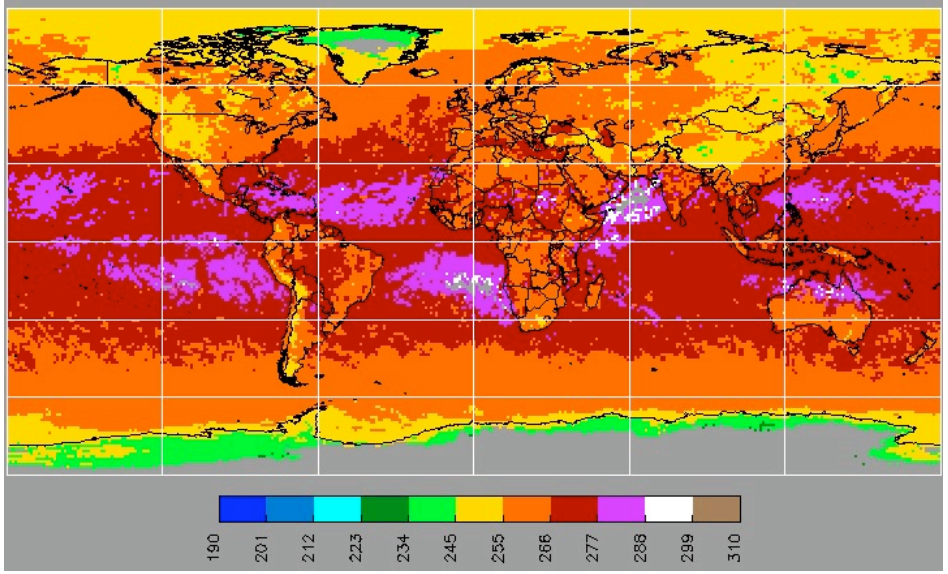
Nighttime Upper



Daytime Lower

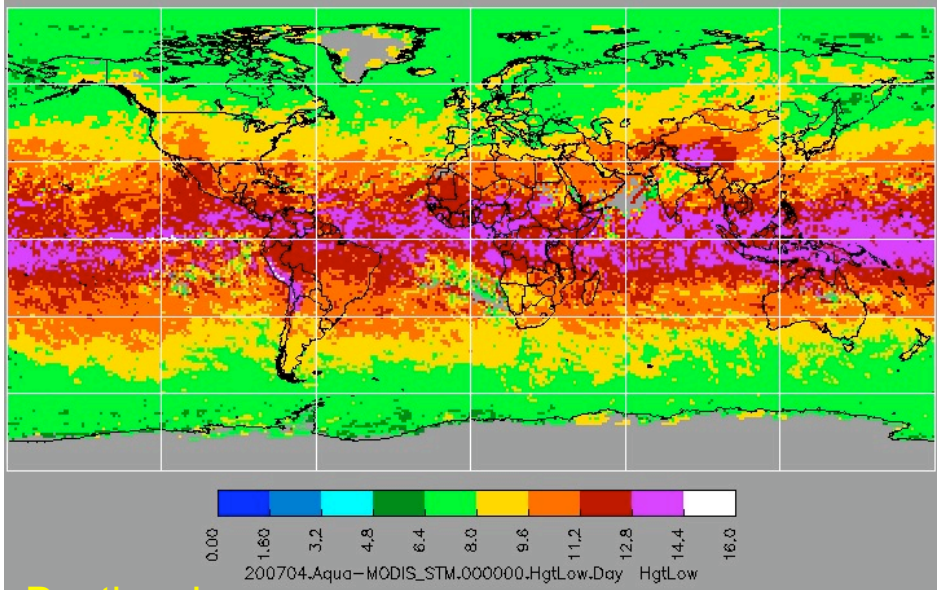


Nighttime Lower

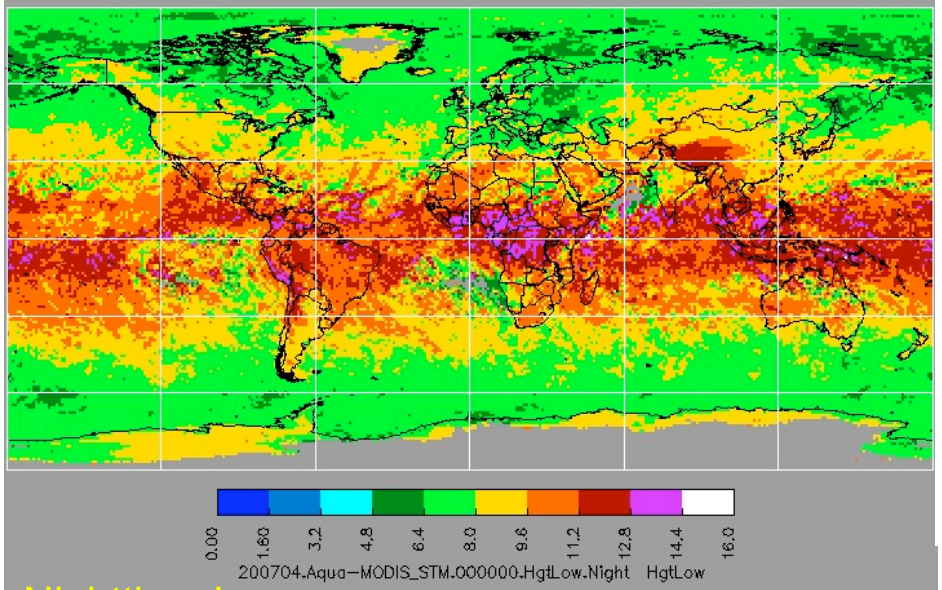


CERES Ed4 Upper & Lower-Layer Cloud Top Heights

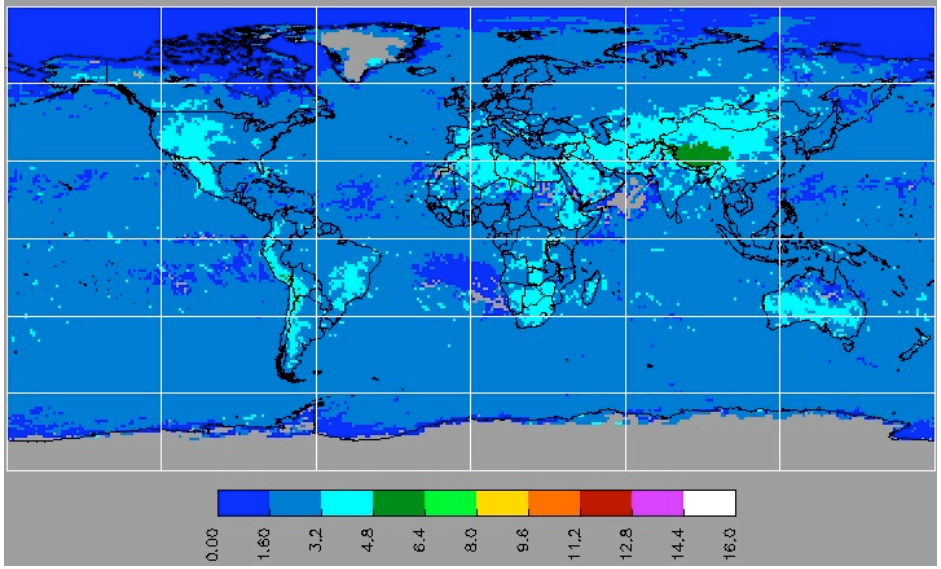
Daytime Upper



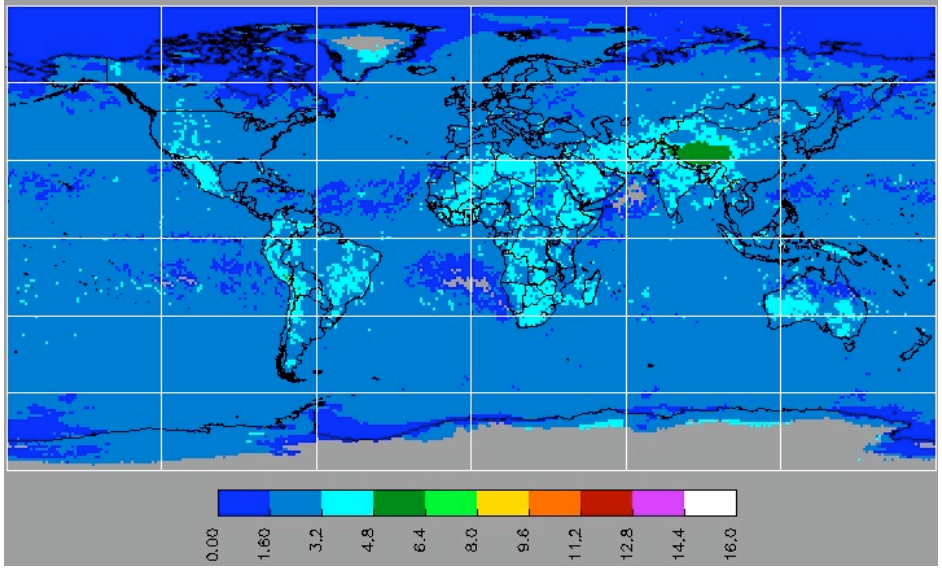
Nighttime Upper



Daytime Lower

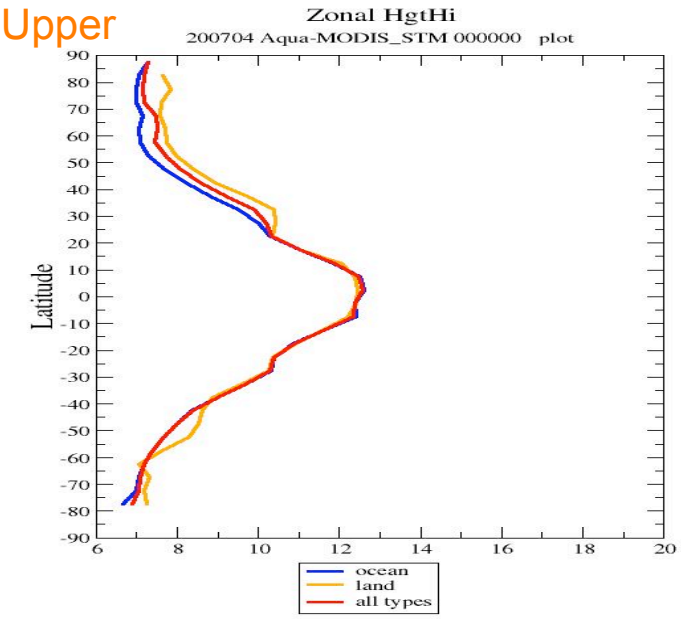


Nighttime Lower

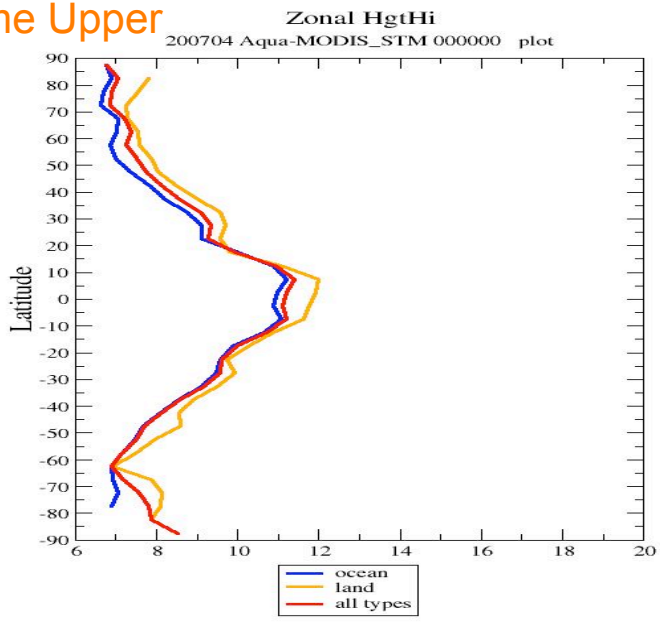


CERES Ed4 Upper & Lower-Layer Cloud Top Heights

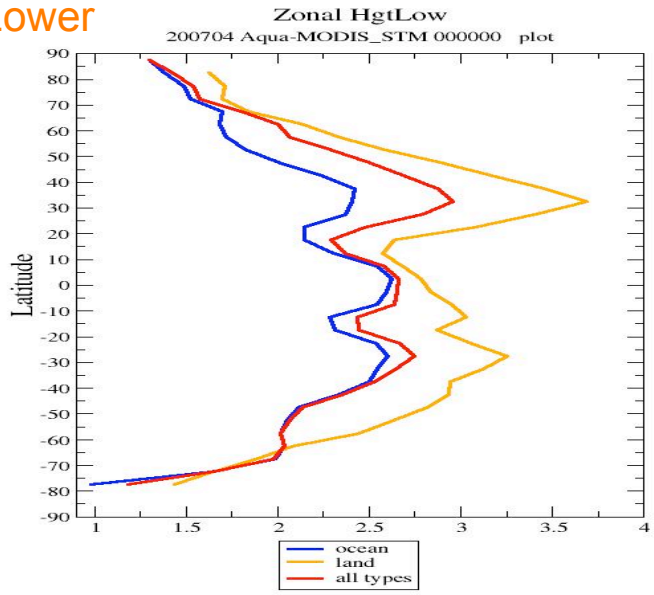
Daytime Upper



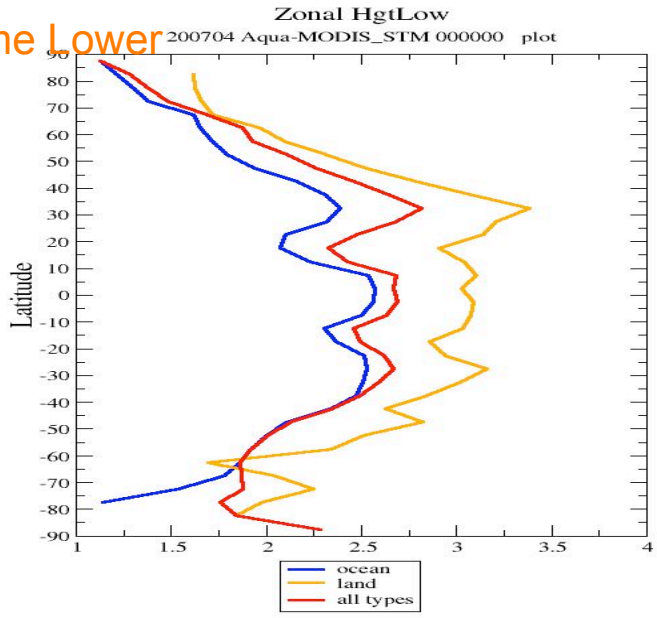
Nighttime Upper



Daytime Lower

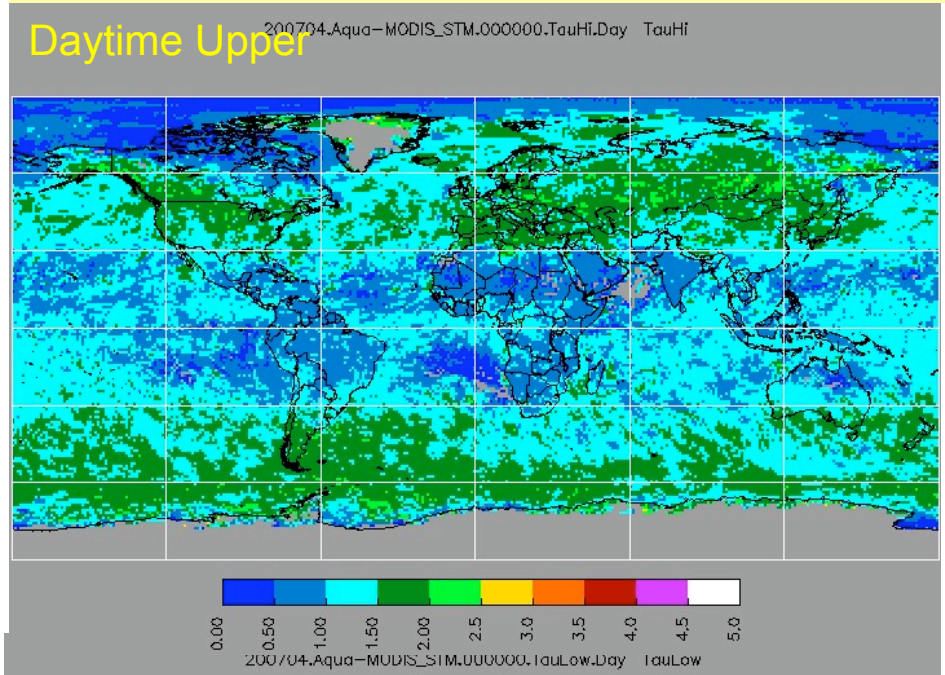


Nighttime Lower

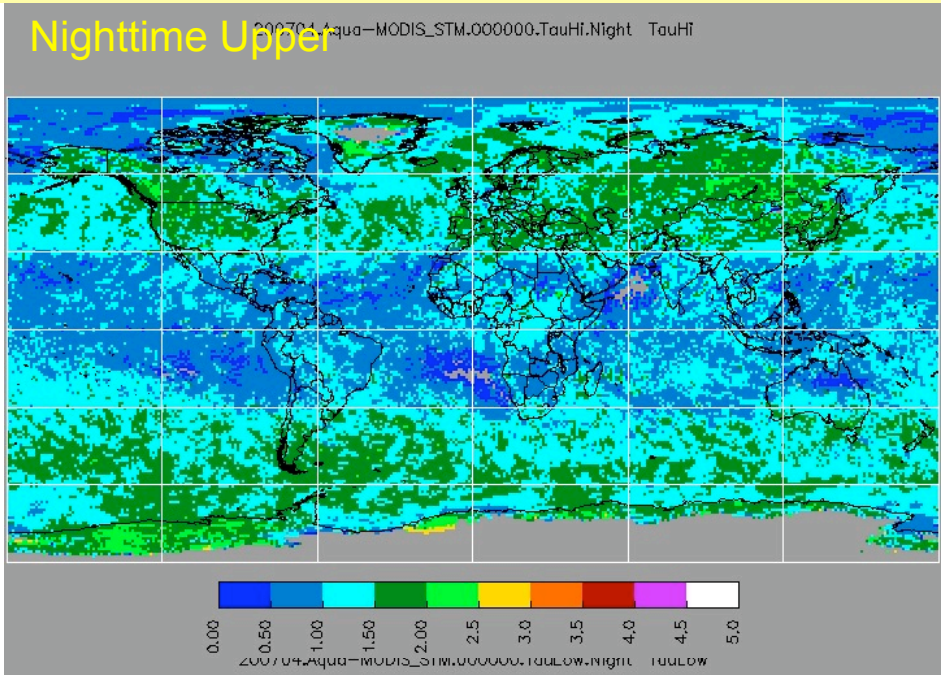


CERES Ed4 Upper & Lower-Layer Cloud Optical Depths

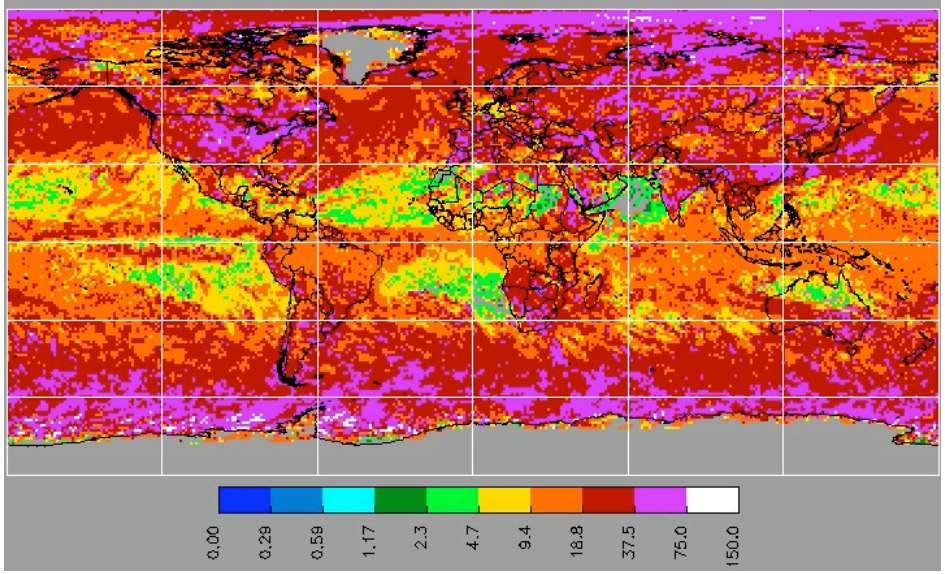
Daytime Upper



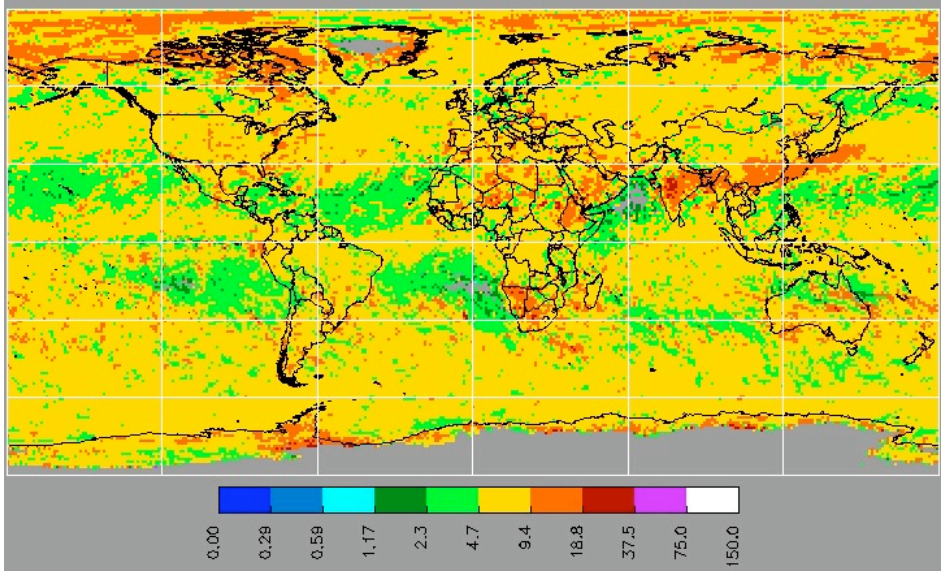
Nighttime Upper



Daytime Lower

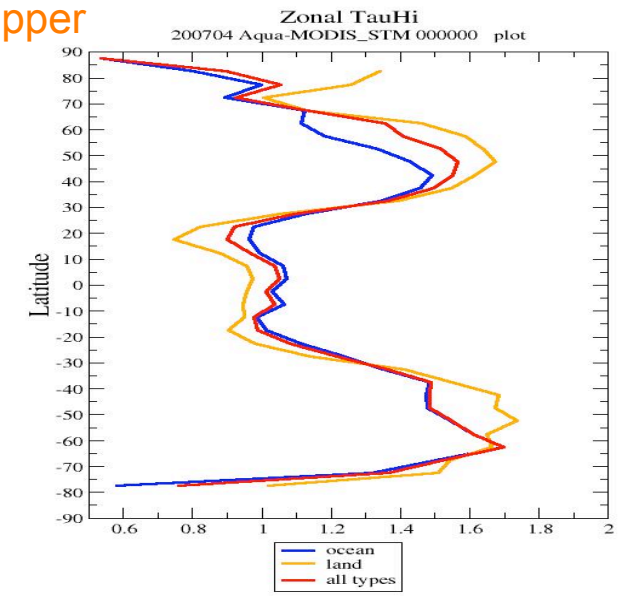


Nighttime Lower

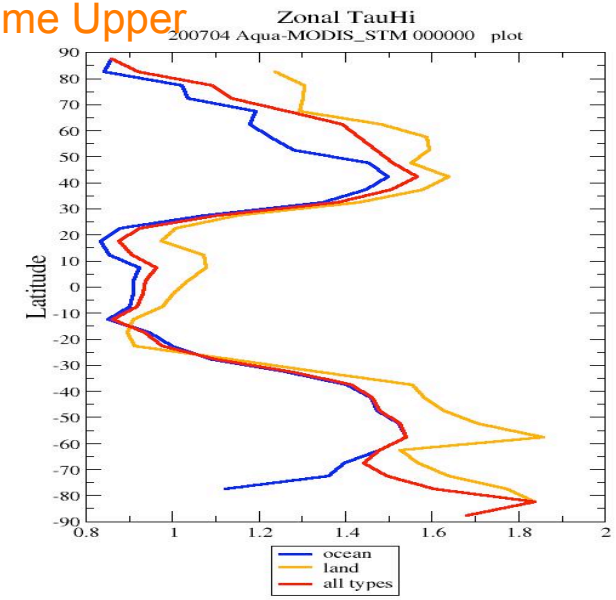


CERES Ed4 Upper & Lower-Layer Cloud Optical Depths

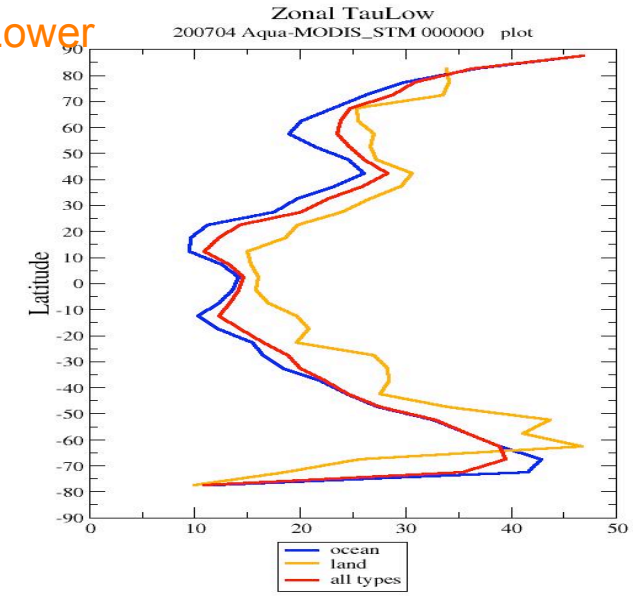
Daytime Upper



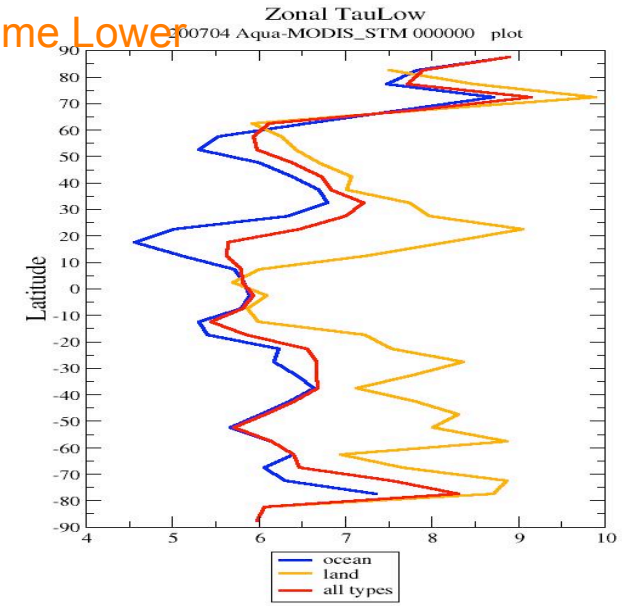
Nighttime Upper



Daytime Lower

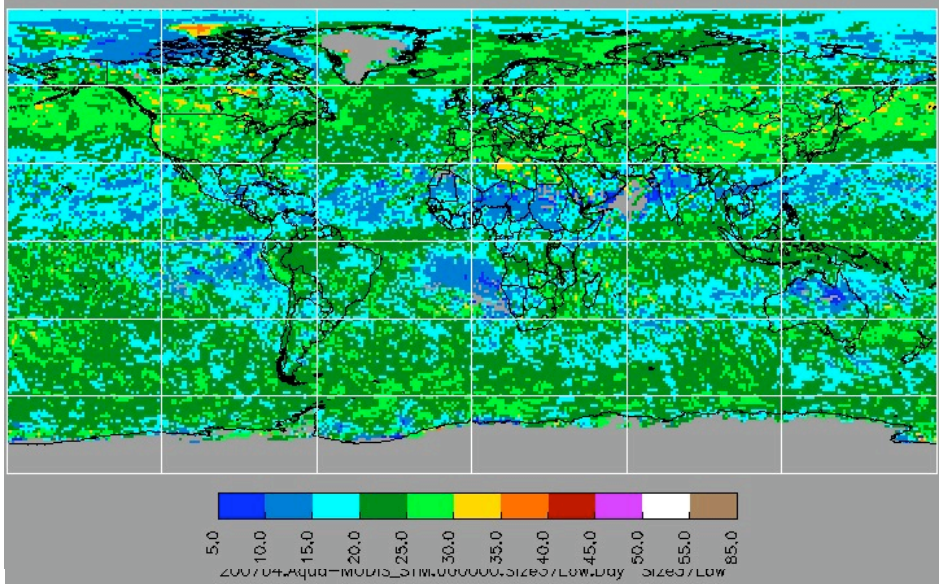


Nighttime Lower

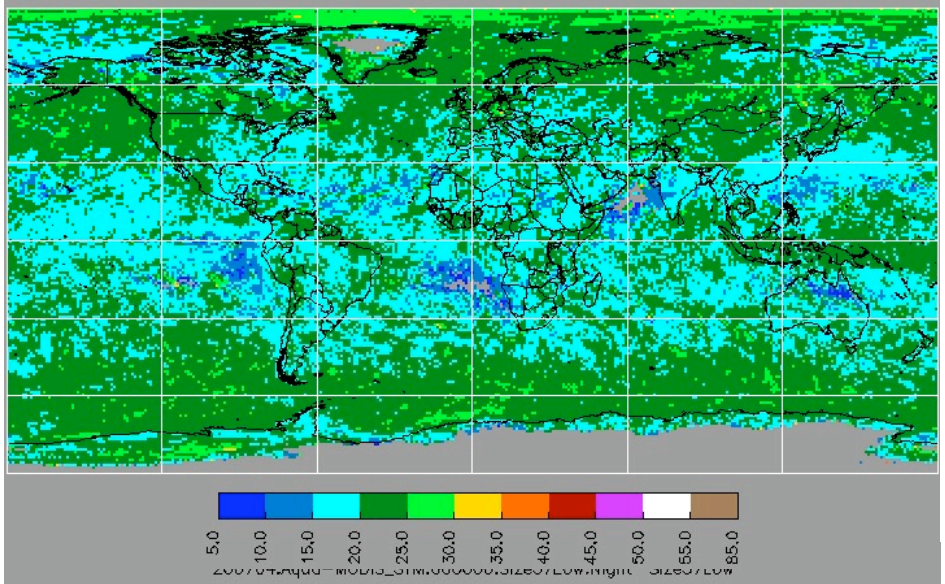


CERES Ed4 Upper (ice) & Lower (water) 3.7-μm Effective Radii

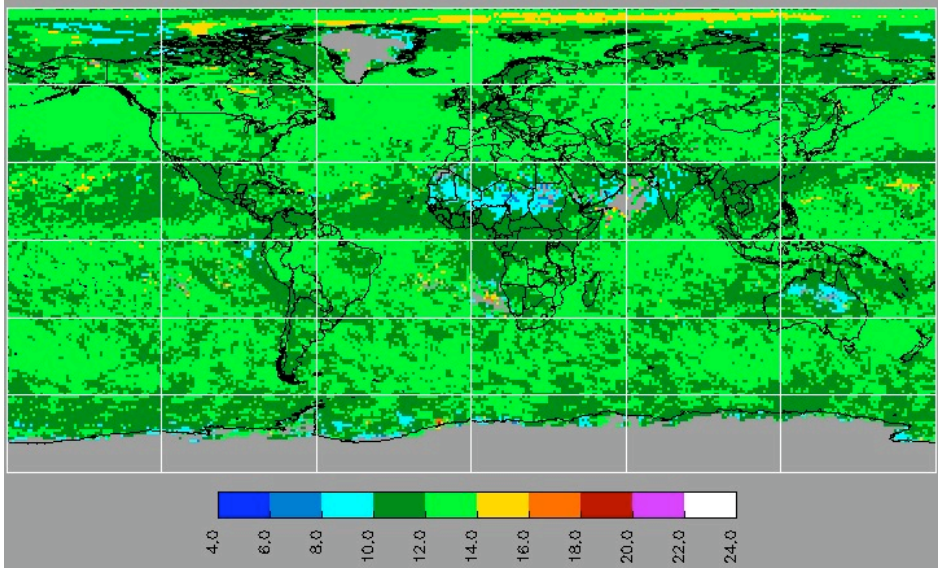
Daytime Upper



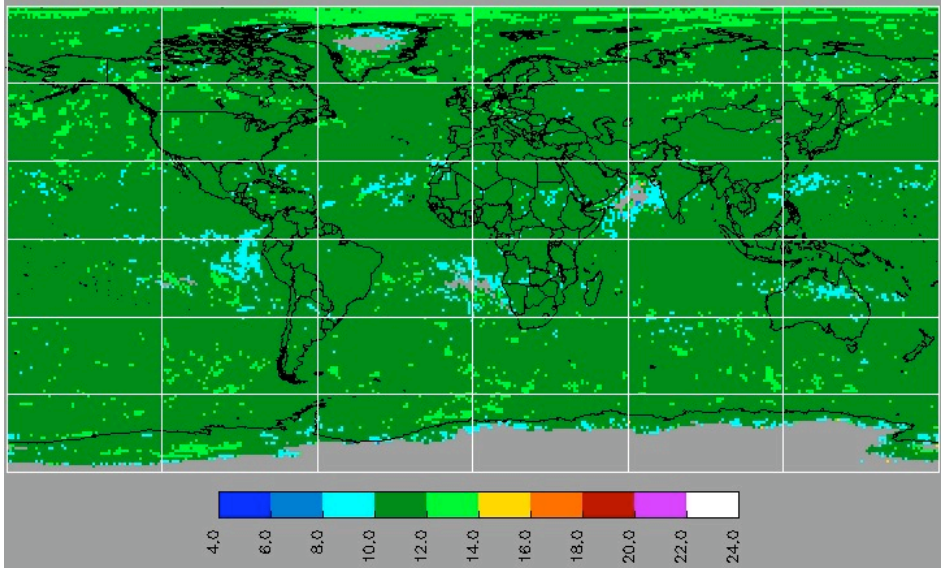
Nighttime Upper



Daytime Lower

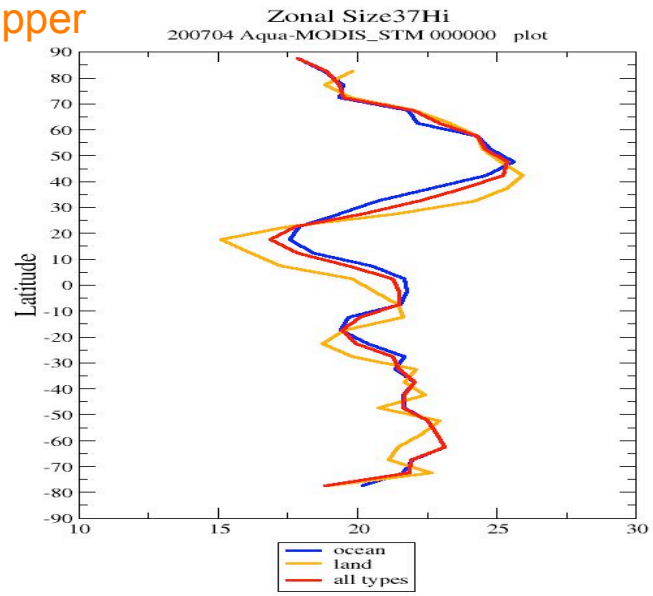


Nighttime Lower

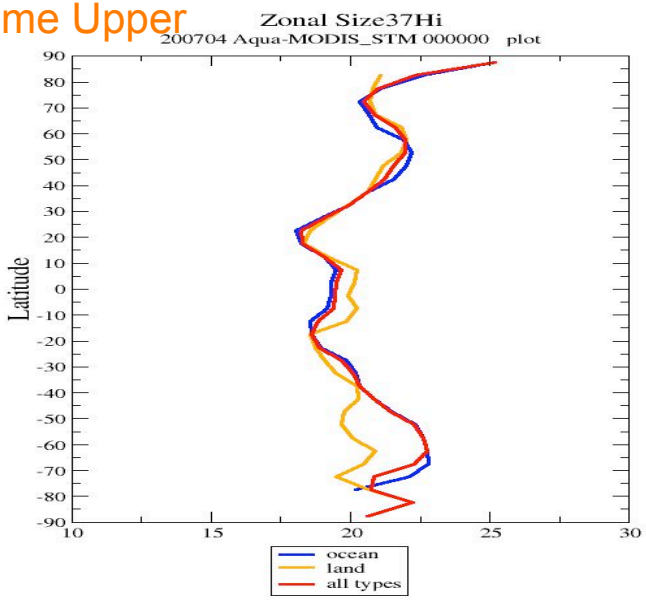


CERES Ed4 Upper (ice) & Lower (water) 3.7-μm Effective Radii

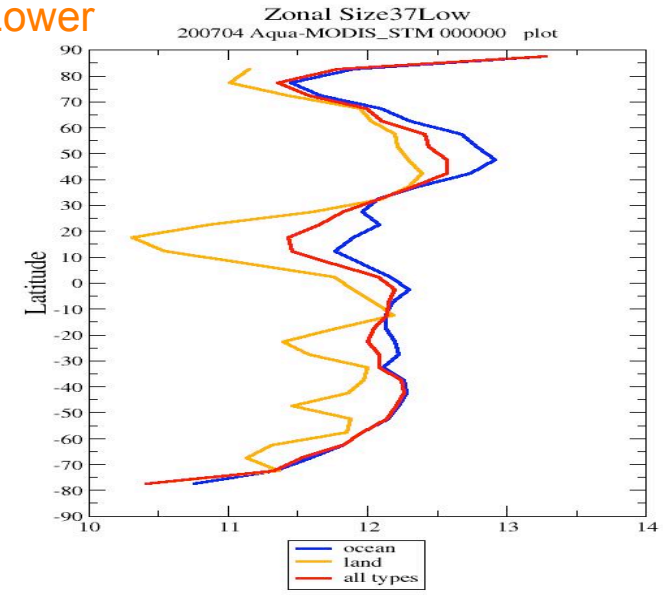
Daytime Upper



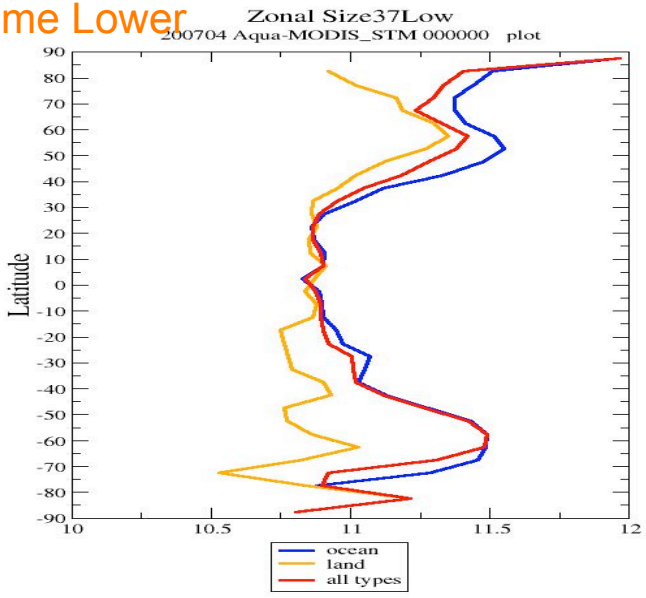
Nighttime Upper



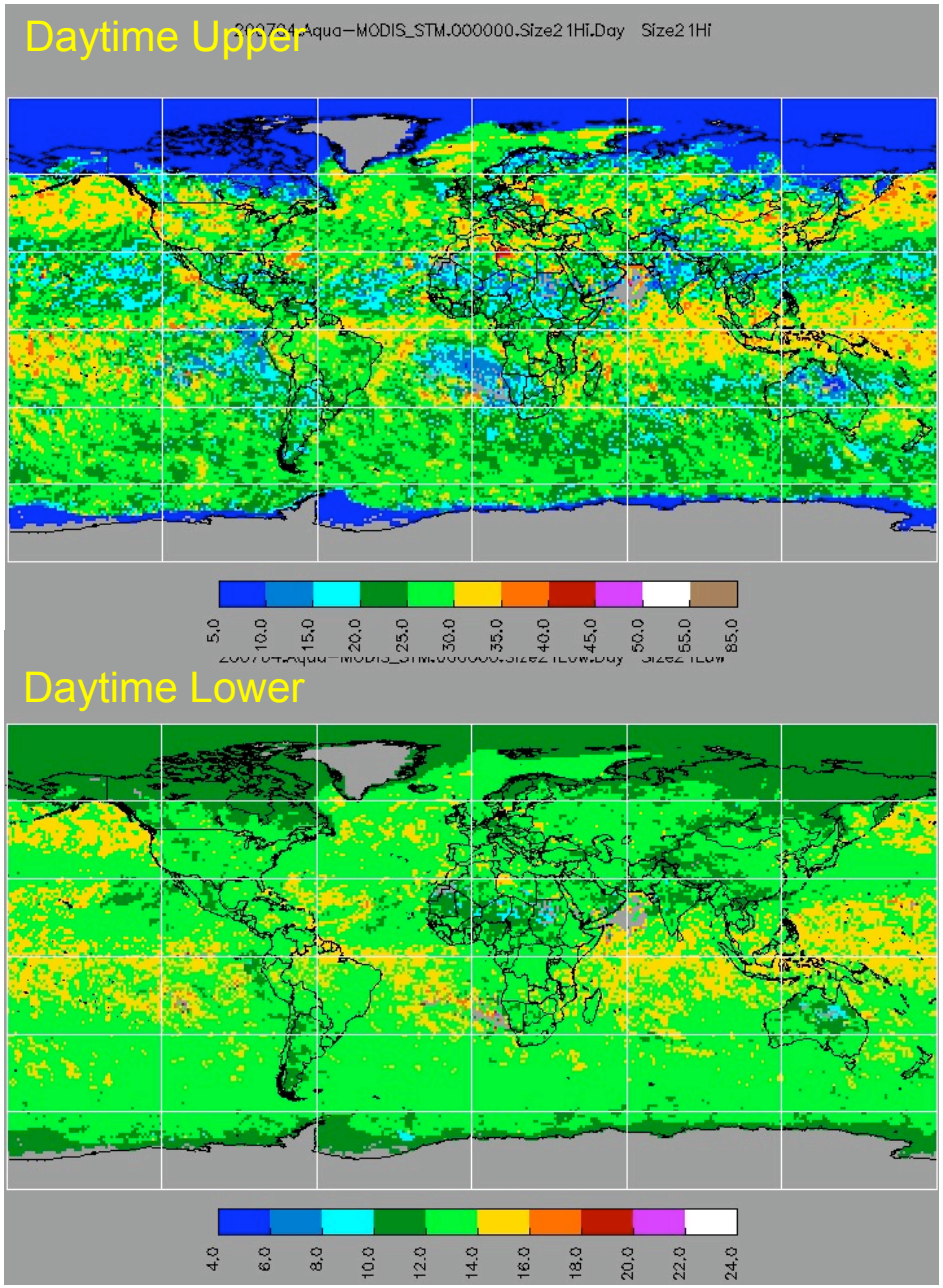
Daytime Lower



Nighttime Lower



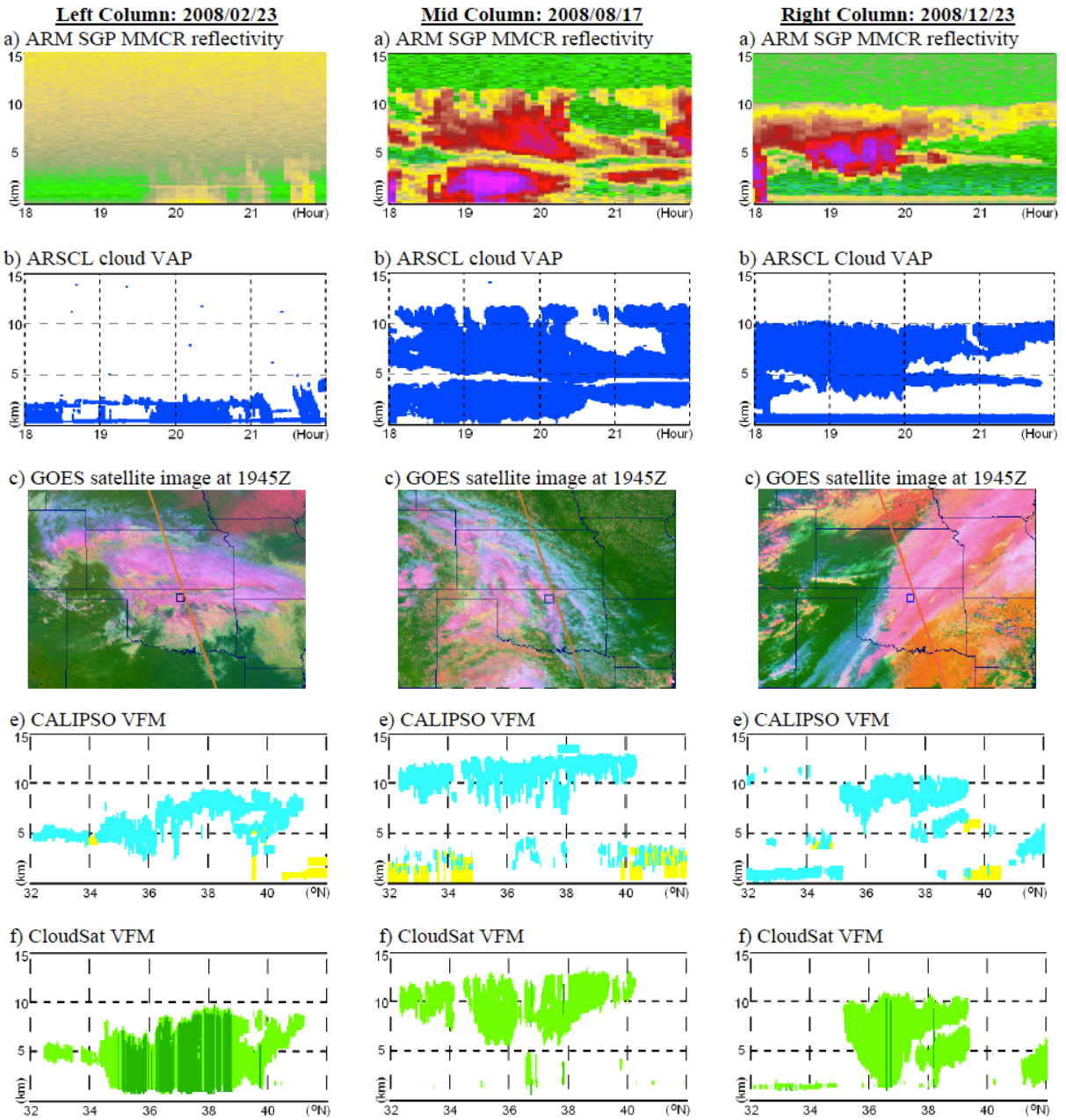
CERES Ed4 Upper (ice) & Lower (water) 2.1-μm Effective Radii



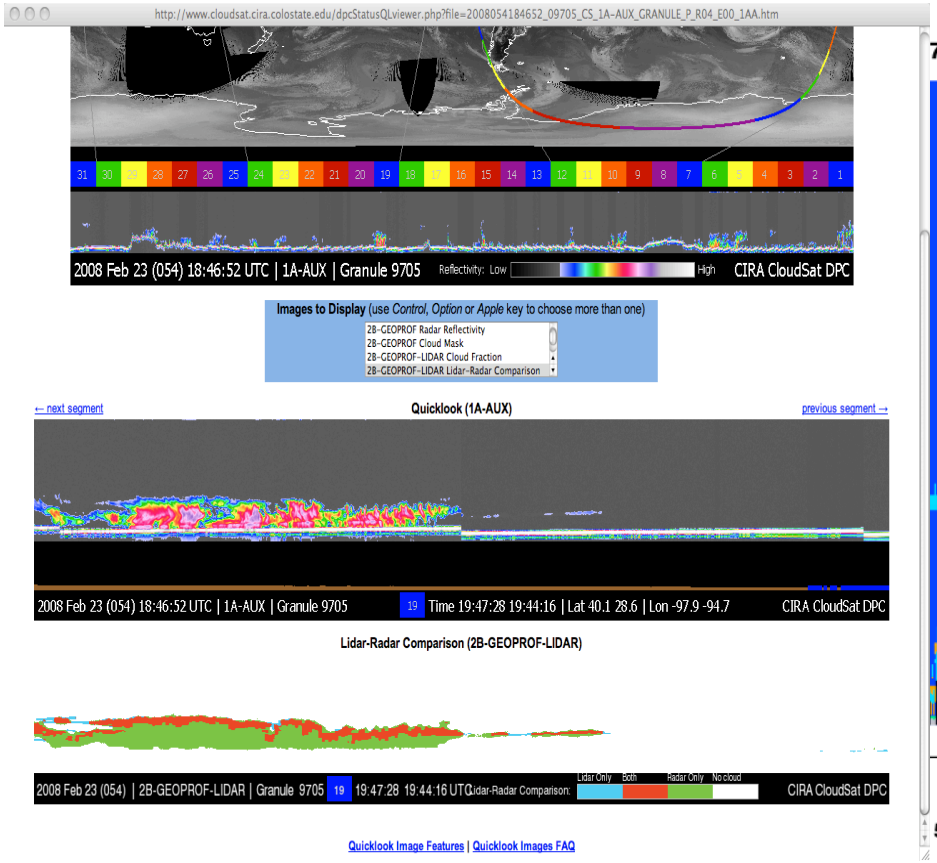
- A coding error was found in the 2.1-μm upper Re/lower re retrievals over the snow/ice land surface.
- The cause: Initial guessed value was erroneously set to zero.

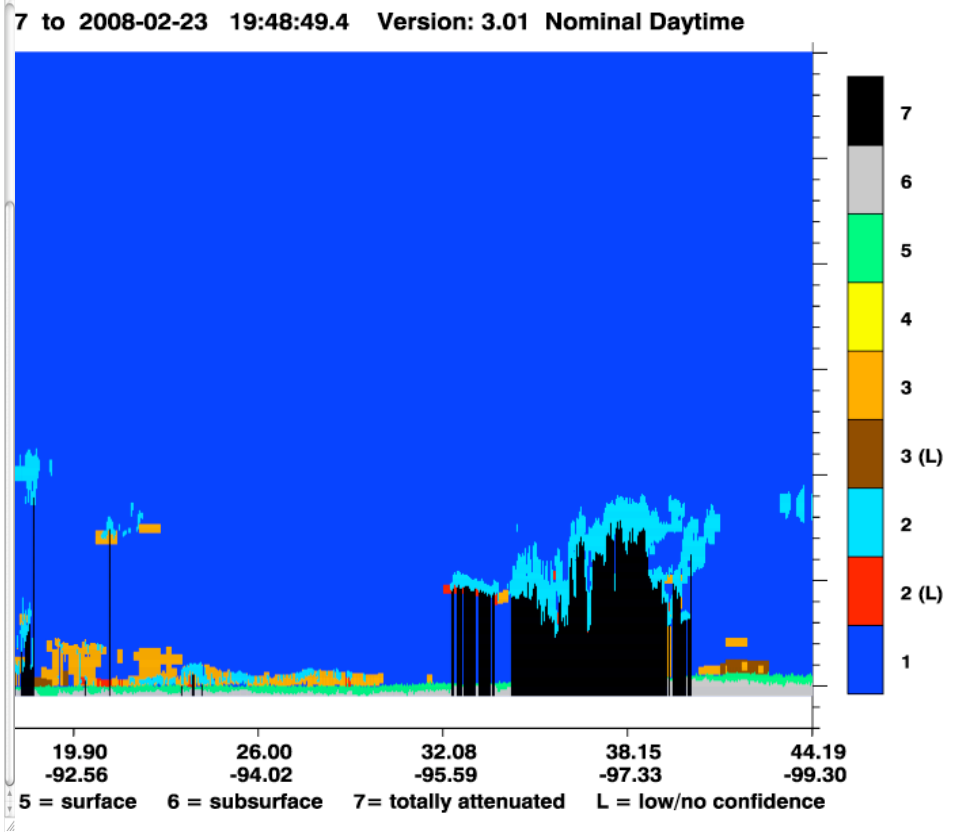
Aspects of Passive & Active Satellite Remote Sensing

Why & What were the differences among the ground- and satellite-based active sensing?

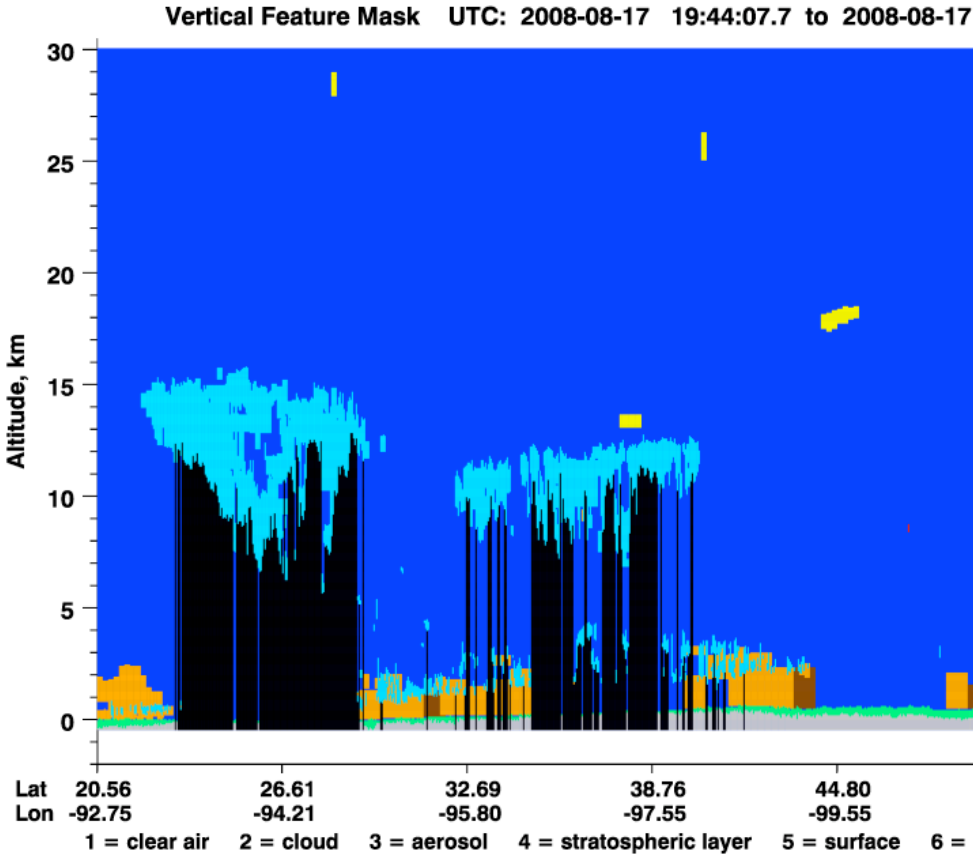


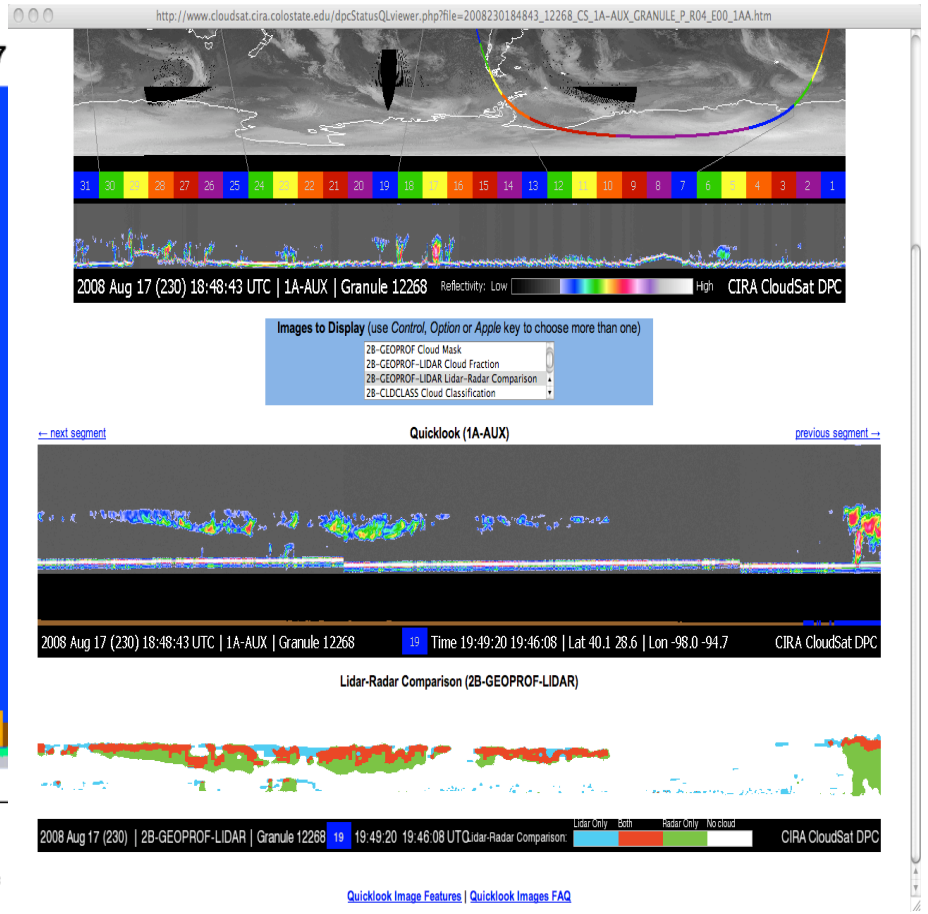
Active Remote Sensing: CALIPSO and CloudSat (case 1)



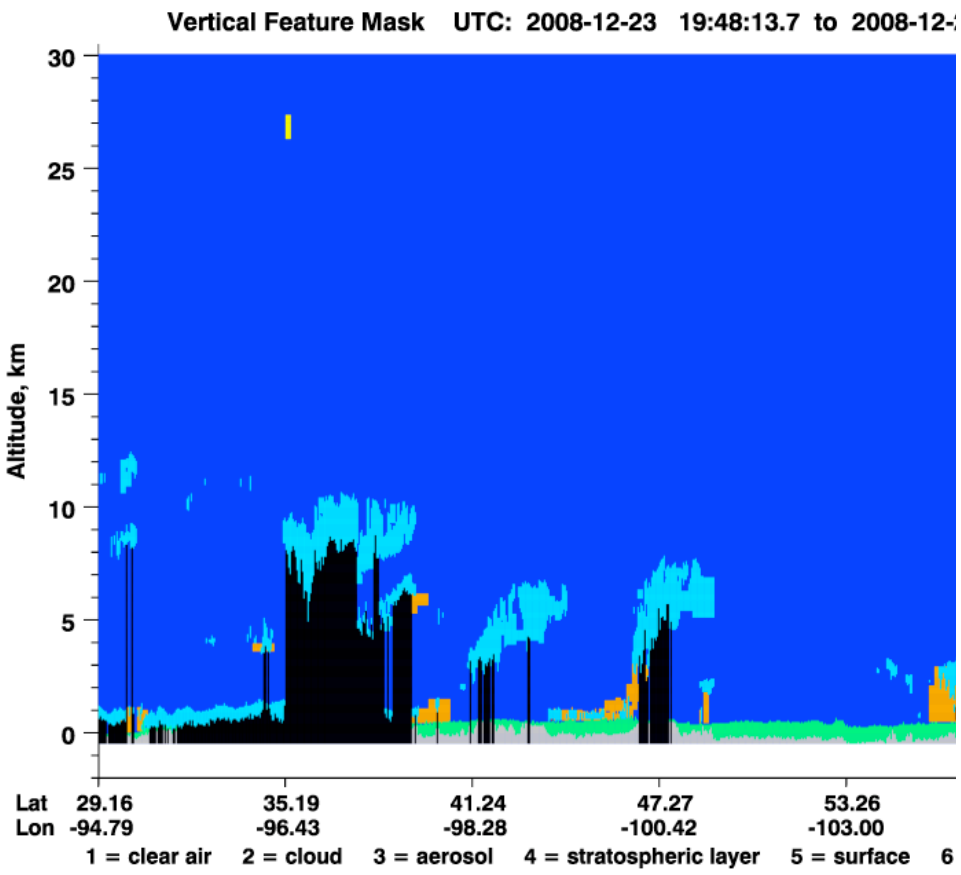


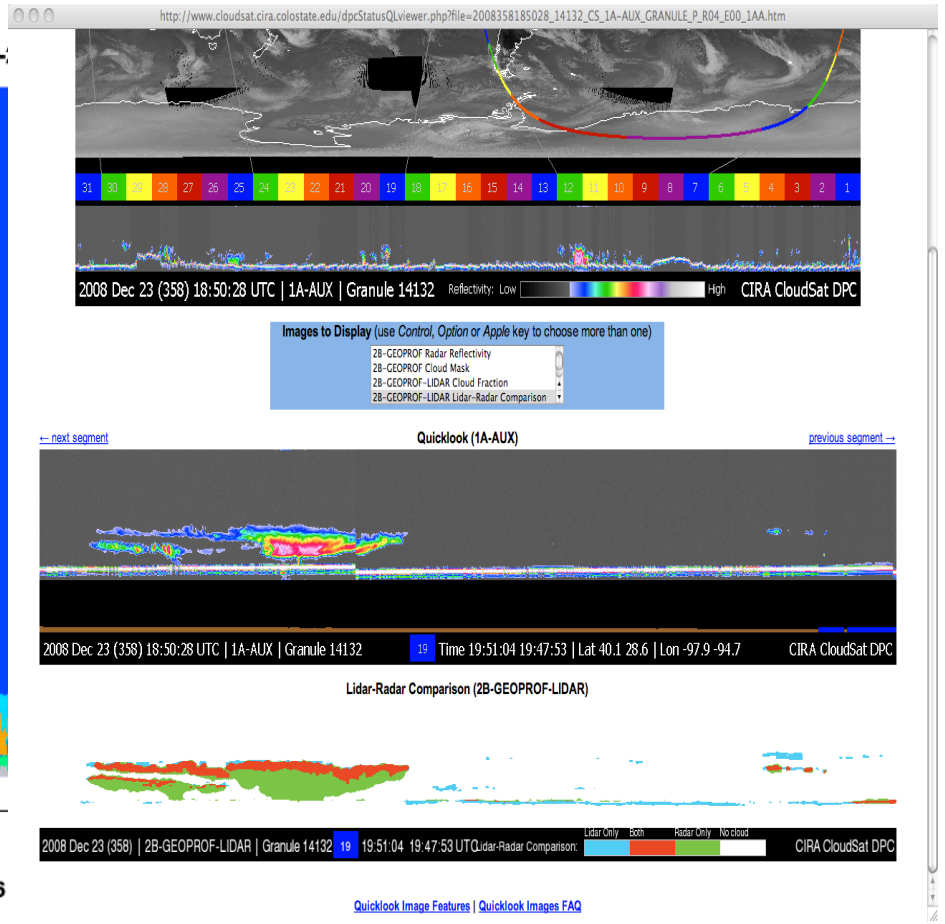
Active Remote Sensing: CALIPSO and CloudSat (case 2)





Active Remote Sensing: CALIPSO and CloudSat (case 3)

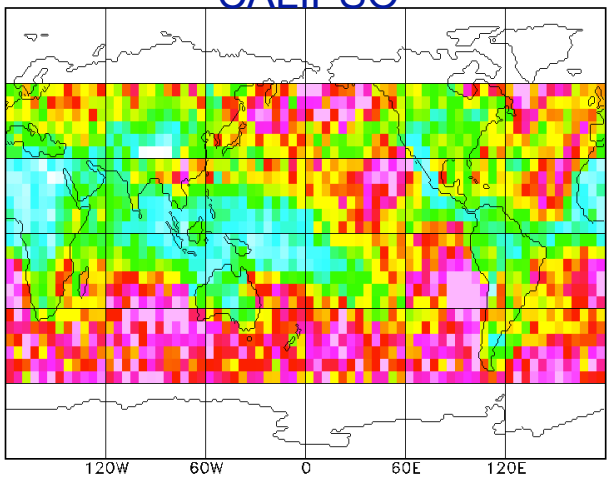




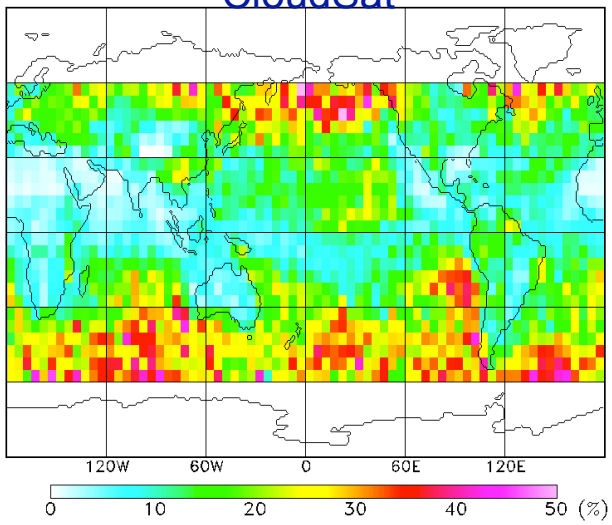
CALIPSO and CloudSat Detected Cloud Fractions: 2007 March-May

Low cloud only > 500 mb

CALIPSO

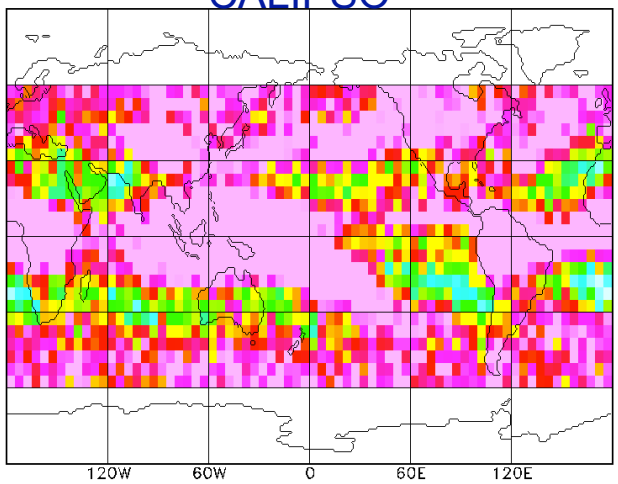


CloudSat

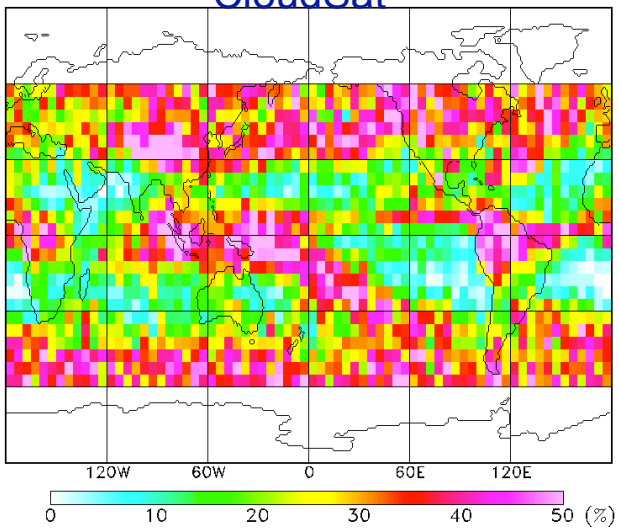


High cloud < 500 mb

CALIPSO

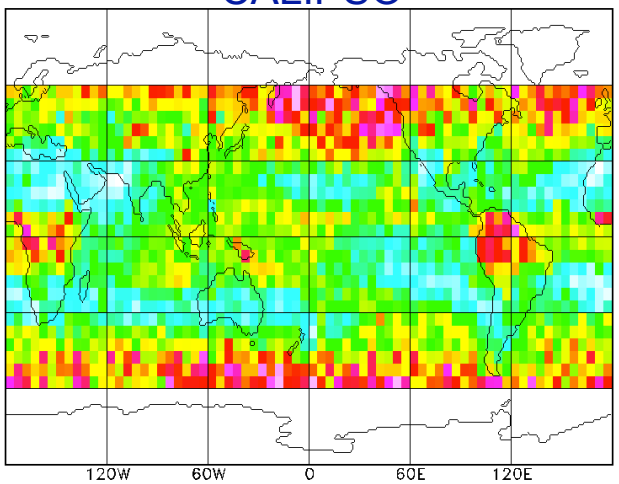


CloudSat

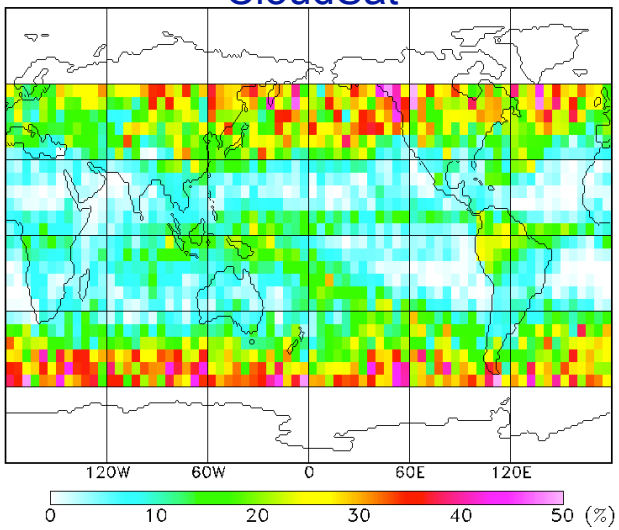


High + low clouds

CALIPSO



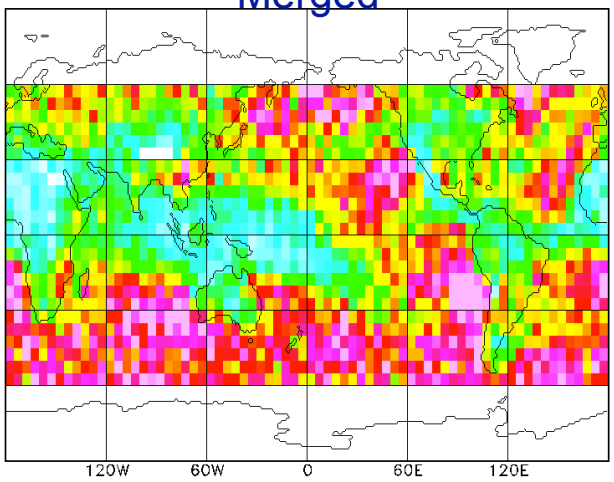
CloudSat



CALIPSO/CloudSat/CERES (Ed2) Merged and CERES Ed4 Multilayer Cloud Fractions: 2007 March-May

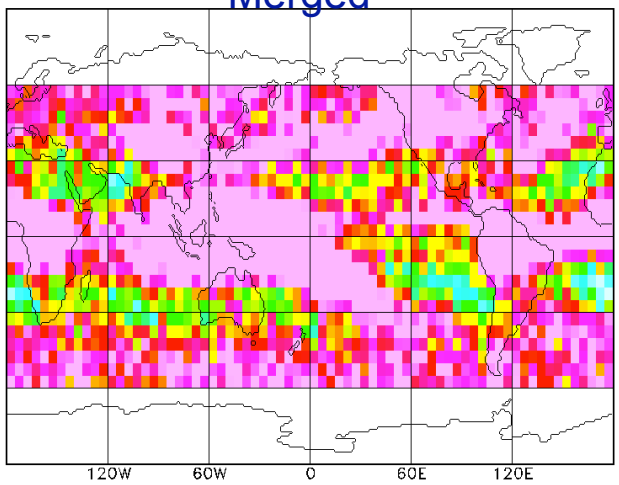
Low cloud only > 500 mb

Merged



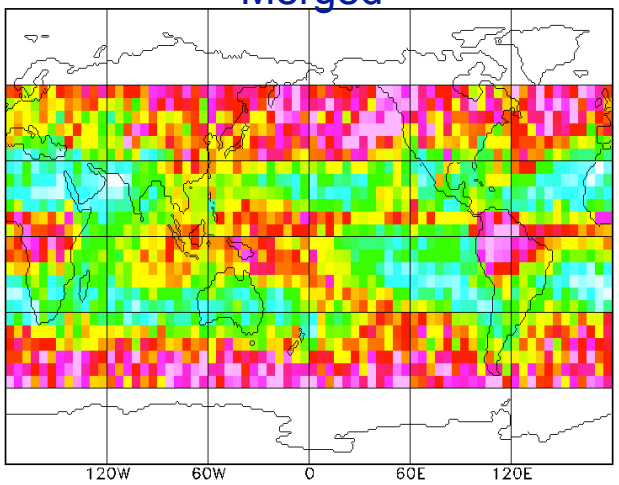
High cloud < 500 mb

Merged

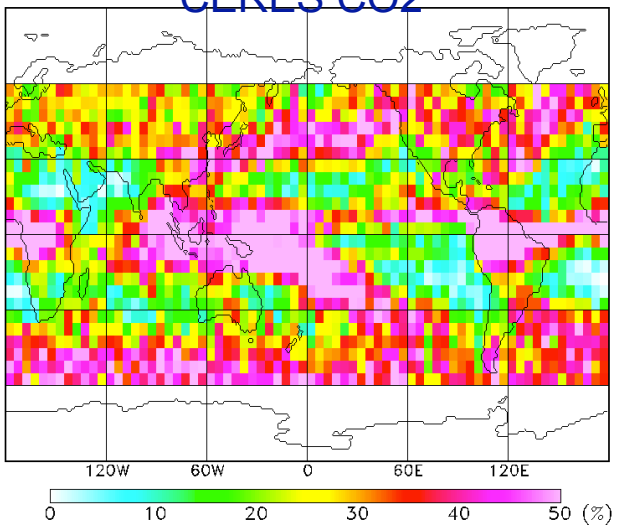


High + low clouds

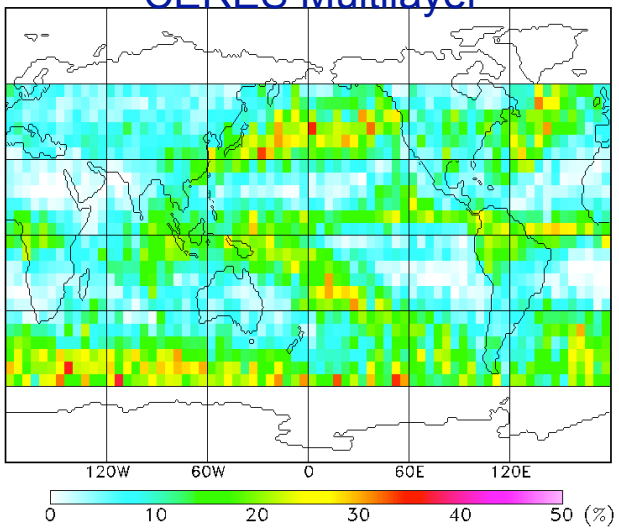
Merged



CERES CO2

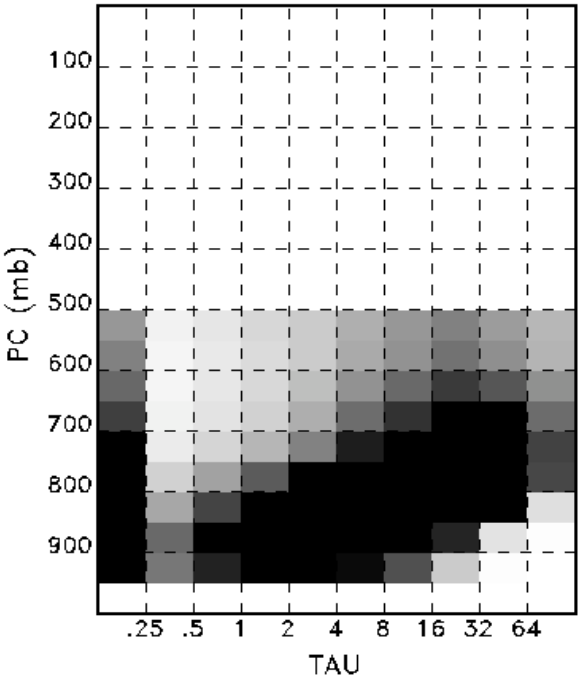


CERES Multilayer



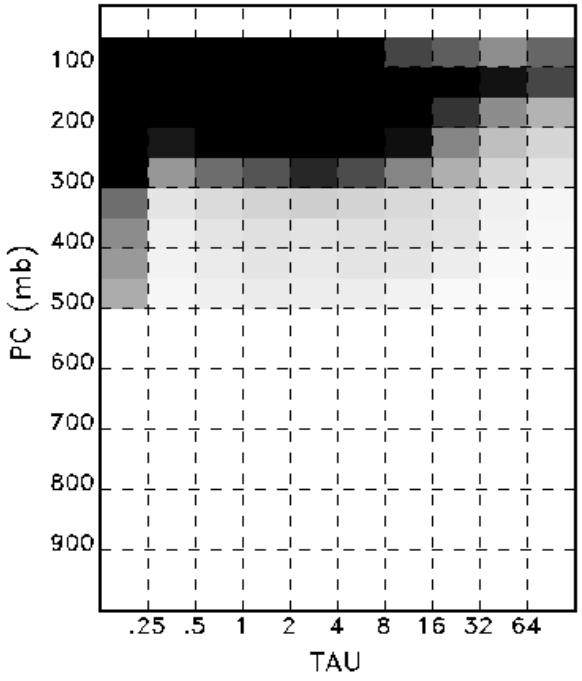
CALIPSO/CloudSat & CERES (Ed2) Merged Pc/Tau Histogram In Three Categories: 2007 March-May

Low Cloud:
Profile's Top Pc > 500mb
27%



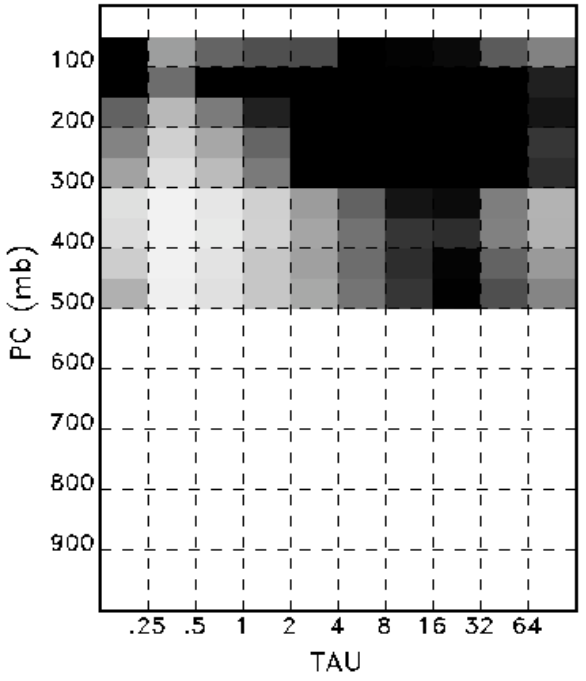
CERES Multi fraction
0.2%

High Cloud:
Profile's Bottom Pc < 500mb
19%



CERES Multi fraction
2.5%

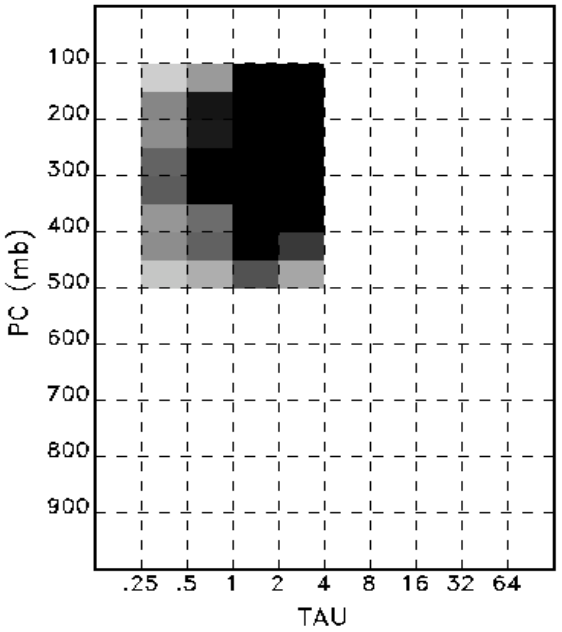
High/Low Cloud:
Top<500mb; Bottom>500mb
27%

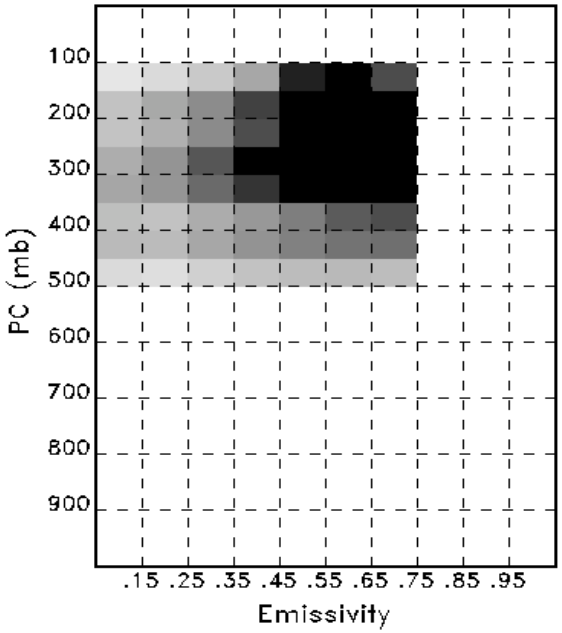


CERES Multi fraction
7.0%

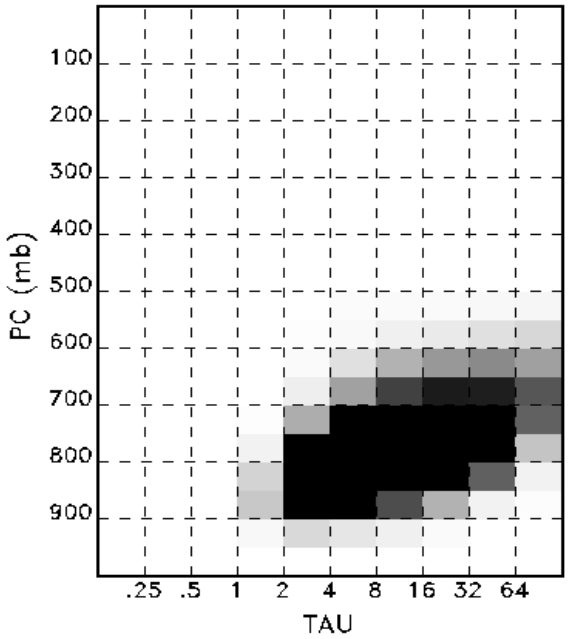
CERES Ed4 Multilayer Pc/Tau and Pc/ε_c Histograms (2007 March-May)

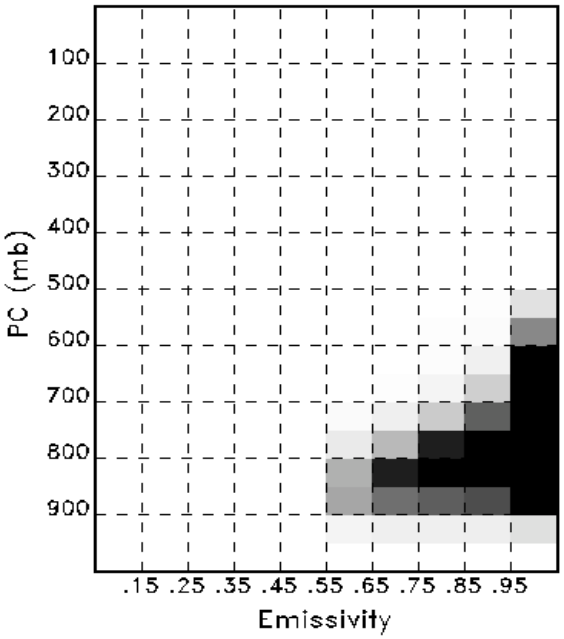
Upper-layer





Low-layer





Conclusions

- The first look at the CERES Edition 4 multilayer cloud properties showed reasonable agreement with the C3M data.
- The upper- and lower-layer cloud parameters when retrieved are expected to better characterize not only the cloud vertical locations, but also the radiative effects in the infrared/longwave and visible/shortwave due to ice over water clouds.
- However, the CERES Edition 4 multilayer cloud retrievals are limited to 1) the upper-layer cirrus cloud with a visible Tau > 0.25 and an infrared emissivity $\varepsilon < 0.75$ and 2) the underlying lower-layer water cloud with a visible Tau > 1.
- The first survey showed CERES Ed4 multilayer cloud fractions ~10% globally. This evaluation of the CERES Ed4 multilayer cloud parameters is not final and still on going!
- Future work, we will use the new C3M data produced with the CERES Ed4 Clouds.